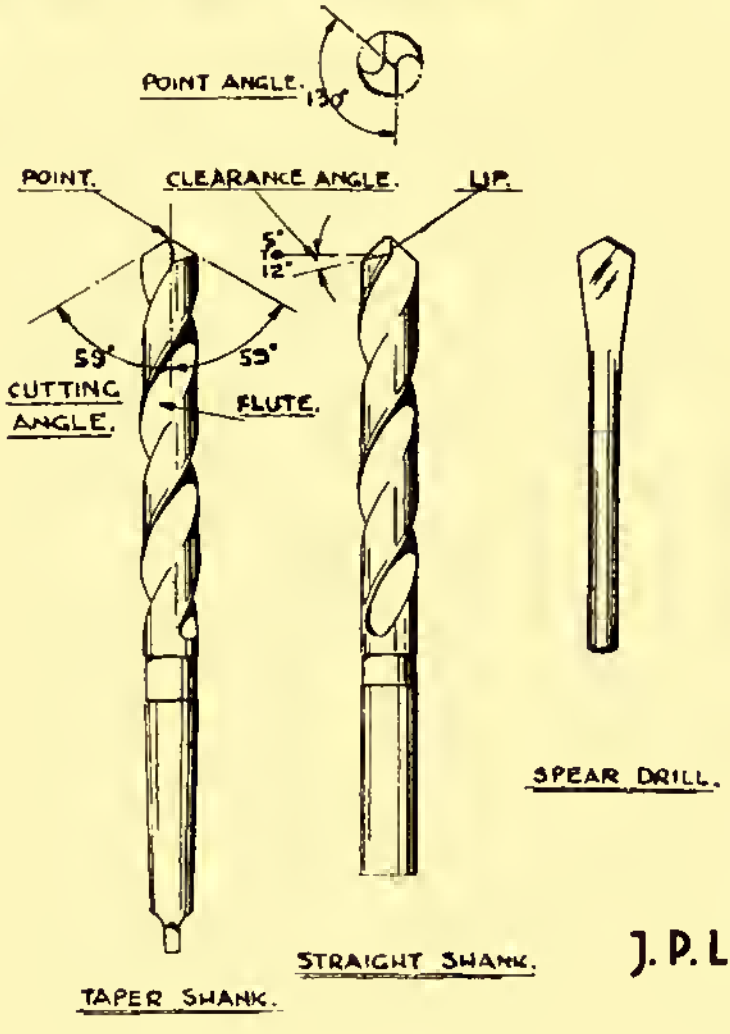
THE BEGINNER'S GUIDE TO FITTING



J. P. LAW

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By

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PREFACE

I would like to record my thanks to Mr. Pendril Davies for his work in reviewing the book and also to Mr. L. G. Miles for his practical help and encouragement without which it would never have been written. I would also add my appreciation to the personnel of Hawker Aircraft Ltd. for their help and co-operation.

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CHAPTER I

VICES

The fitter holds his work in a vice. This should be firmly secured to the bench by means of bolts. Coach screws are sometimes used but they invariably work loose unless the work is of a very light nature.

If you are a person of average build, the best height for your vice is about forty-two inches. At this height the top of the vice will come level with your elbow, and you will be able to work comfortably without straining on your toes or bending your back.

The height of the vice is particularly important when filing, a subject which will be dealt with later.

The vice jaws are of hardened steel and should be parallel when the vice is closed. The jaws are serrated to grip work firmly, but a great many jobs would be spoiled by gripping in the serrated jaws and therefore false or soft jaws are introduced between the work and the hardened faces. Soft jaws may be made of brass, copper, lead or mild steel. In Fig. 1 is shown a typical pair of soft jaws.

Old brass or mild steel soft jaws gradually take on impressions of the work they have held, and also pick up pieces of steel which make the jaws almost as bad as the hard vice face, so they should be cleaned regularly and scrapped when they become cracked or pitted. If you want to prove the truth of this, take any piece of steel having a smooth face and grip it hard in the vice between a pair of old soft jaws, and you will see, on releasing it, the impressions of the faults in the jaw clearly stamped on the work. The usual height for a vice has been given as forty-two inches, but for fine instrument work, a vice a few inches higher is more suitable and for heavy work a vice forty inches high will be found more practical.

There are several easy ways to break or ruin a vice. If an object is gripped very tightly on one side of the jaws only, there is great danger of the jaws breaking off.

If then you want to hold work very tightly on one side, put a piece of scrap steel of the same approximate width on the other side and tighten up.

The vice handle is of sufficient length to tighten the vice firm enough for almost any work.

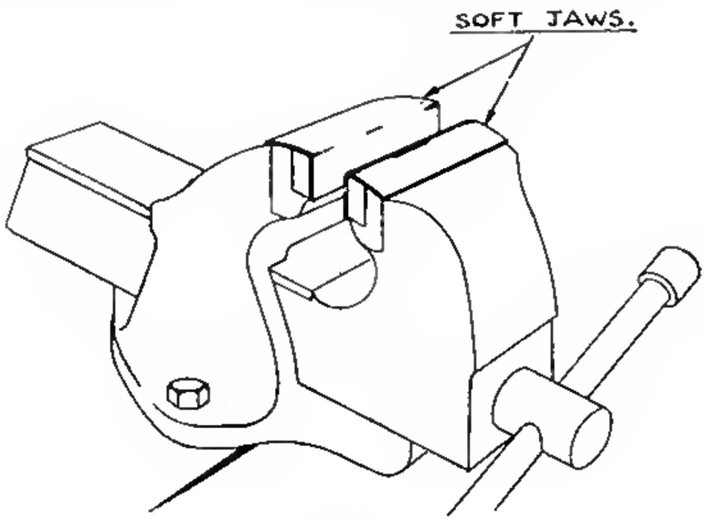


Fig. 1

It is a mistake to strike it with a hammer, this strains the screw and marks the handle, furthermore, if the vice screw is in a strained condition while holding the work, it may suddenly strip and if the work is heavy you may be injured, which will be no less than you deserve for lack of common sense.

If you have the job of fastening your own vice on the bench, see that when you grip a long piece of steel in the side of the vice, it will clear the bench.

The back of a vice is not an anvil, and a blow is sufficient to break the vice completely in half.

The sliding parts should be cleaned and oiled weekly, cleaning first with paraffin and jute and oiling on the slides

by means of a few drops of oil transferred from the finger.

Only bad workmen mark their vices by incorrect use of files, hacksaws and chisels, but as these instruments have not yet been mentioned, we had better proceed to the next chapter.

CHAPTER II

FILING WITHOUT TEARS

To a beginner, a file seems a difficult instrument to manipulate. It is true that considerable practice is required before a fitter can file with sufficient skill to make the result acceptable in a workshop, but filing is not a purely mechanical action and a file cannot be successfully guided by the body only, therefore, while practice is very necessary, the tedium will be very much reduced and success very quickly accelerated if the beginner combines the observance of his eye and the powers of his mind with the action of his body.

A boxer who fought with his arms crossed would hardly be successful. He stands in a natural easy manner and one most suited to offence and defence, similarly, a man using a file must be in the right position relative to his vice and his work. In Fig. 3 will be seen the best position to stand when filing.

Use the *whole length* of the file.

A file only cuts on the forward stroke, pressure on the backward stroke is a waste of energy and blunts the file teeth.

The legs should not be rigid and the elbow must be kept near to the body.

The file handle will be gripped naturally with the thumb on top. The position of the left hand is shown clearly in the sketch. For a left-handed person, of course, the positions will be opposite. The body will be bent to such a degree that the eye may easily see what is happening to the work.

It is better to file with a sweeping action from right to left and when the surface appears flat to cut from left to right. In this manner the path of the file may be clearly seen.

The eye is quickly trained to detect a flat surface. A

badly filed, uneven surface would appear as in Fig. 4.

But a true plane would appear like Fig. 5.

The eye at once detects the high ridge in the first sketch and tells the workman that he is filing a curve from left to right and also filing up in front and down at the back.

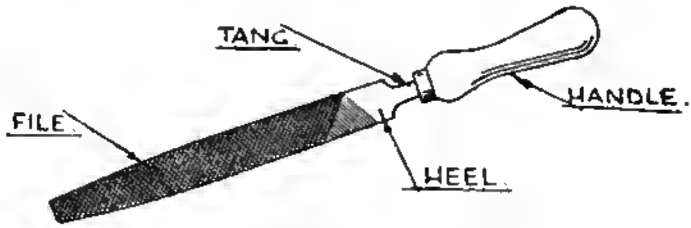


Fig. 2

Now he must strive to control the file and correct his error. By means of an engineer's square he checks the accuracy of his work. (Fig. 6.)

See that your file handle is firmly fixed to the tang of the file and in a straight line with it.

A handle is best fixed by the following method :—

First get an old file of approximately the same size and

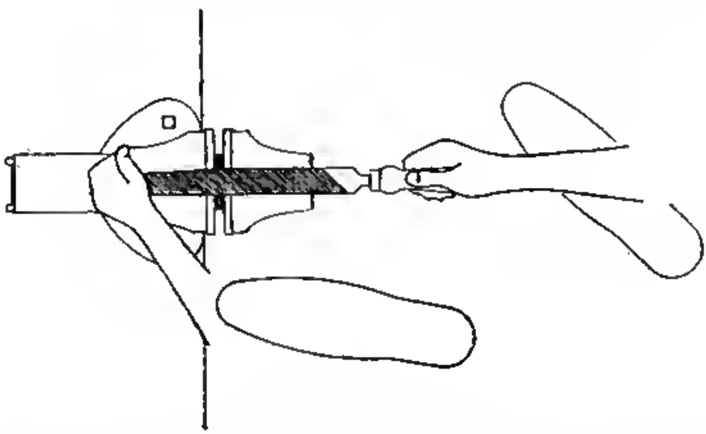


Fig. 3

make the tang red-hot in a fire, then holding the handle in a vice, push the red-hot tang straight into the file handle until it is deep enough to hide half the tang. The file may then be fitted. If the file is a new one, it is wise to lightly chalk the

surfaces before use. This prevents the particles of steel from sticking to the grease which is always present in a new file.

Chalk is also a good help when finishing a surface, if lightly applied to the file teeth.

Special files are designed for filing soft metals such as brass,

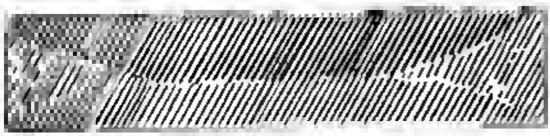


Fig. 4

aluminium, etc., etc., but as these are not always available, it is helpful to remember that a new file is better, if obtainable, for cutting soft metals.

A few hints in conclusion :—

It is a mistake to try and remove large quantities of metal by pressing hard on the file.

A file card should be used regularly to clean the teeth of steel, dust and dirt.

Remember, a file is hard, the teeth are easily broken by bringing it in violent contact with the work or by throwing it among other files or pieces of steel.

The more file teeth that are broken, the quicker will others break, as they have to do an unfair amount of work, the result of this is a lot of unnecessary perspiration from the workman.

A skilled man may use the same file every day for three

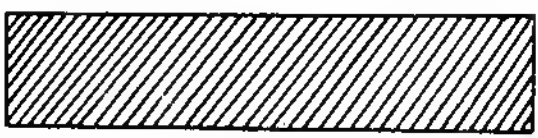


Fig. 5

months without serious wear taking place. When a file becomes unserviceable it takes on a shiny appearance. The tendency of beginners, however, is to ask for a new file when there is still considerable wear in the old one.

When asking for a new file, remember that a file has three dimensions, viz., length, shape, and cut, such as " Ten inch, half round, second cut file." The length of a file is measured from the point to the heel.

If you examine a number of files you will see that the

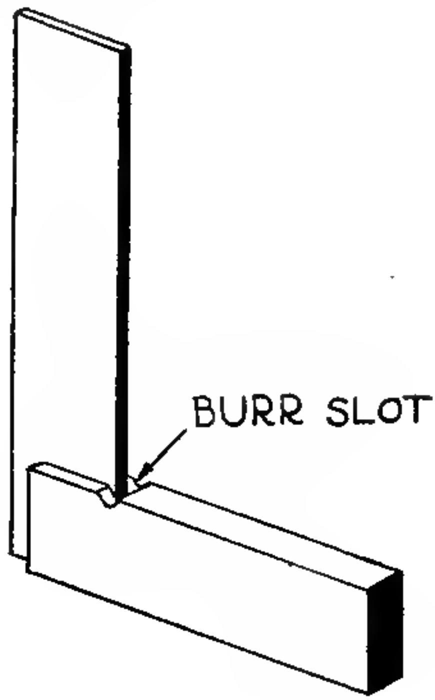


Fig 6

teeth point in one direction only, in other details files vary considerably.

Rough files and bastard files have coarse teeth cut across each other. As these teeth are large and deep they cut a corresponding large amount of metal from the work.

Second cut files usually have the teeth cut one way only and can be compared to a number of knives fastened together, and cutting equal layers of metal.

It will be noticed that the finish of the work after cutting with a second file cut is much smoother than when cutting

with a rough or bastard file. A smooth file possessing a large number of teeth gives a still better finish.

Finally, toolmaker's files or Swiss files, the teeth of which are so fine as to be almost indistinguishable to the naked eye, give the best finish of all, and are only used for fine work or for creating a very good surface on work that has been shaped by coarser files.

Toolmaker's files are supplied in numbers of cut, the usual cuts used being from No. 0 cut up to No. 6 cut.

Most flat hand files have a safe edge which is to safeguard other parts of the work from being injured by the file edge.

If you are a beginner, do not be discouraged by failure of first attempts, for if you persevere you will find skill gradually comes to you.

Draw filing is a method of making a smooth surface on the work after the usual filing has been completed. The file is drawn backwards and forwards over the work, the high points of the file teeth removing only a slight amount of metal, therefore, a smooth finished surface is achieved. The procedure then is first to file with a rough or bastard file until approximately 1/32 in. remains to be filed. Next use a

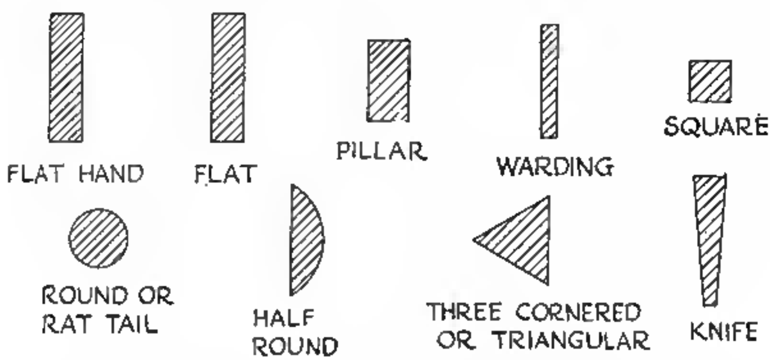


Fig. 7

second cut file until approximately only .010 in. remains to be removed, then draw file using either a second cut or a smooth file. If the surface to be draw filed is a narrow edge, rest the file on the edge until it balances and that position will be the best place to keep the file when draw filing. Both

hands should be kept close to the work. If the hands are wide apart a rocking motion takes place and the surface becomes convex. Take as long a stroke as possible, apply only small pressure, keep the file teeth clear of chips by means

Fig. 7a

of a file card, and use a little chalk on the file teeth. The tendency of the beginner is to draw file *before* enough metal has been removed by filing, the operation, therefore, which should last half an hour may be seen lasting days. The fitter must learn to file with the utmost confidence to the lines he has marked on the work. It should be his aim to split these lines by filing and only draw file to give his work appearance. A handy jig for use in draw filing is shown in Fig. 7a. Used correctly, it enables the fitter to hold the file square with the work and is ideal for use when draw filing edges of metal plate.

CHAPTER III

HOW TO USE A HACKSAW

SINCE a hacksaw is only a thin file, it may be mentioned next. The teeth cut in the *forward direction only*, but as the saw has to sink deep into the material being cut, the teeth are staggered so that a hacksaw not only cuts into the metal in depth, but cuts on the sides as well, so preparing a path wide enough in which to travel.

When filing, the importance of using all the file has been mentioned. When using a hacksaw this rule is even more important. In the sketch (Fig. 8) is shown a hacksaw blade that has been used in one place only from A to B :—

As may be seen that portion only has been worn. Now, when the hacksaw is next thrust forward beyond A, the teeth which are boldly projecting will be torn off, moreover, if a cut of only a small depth is taken by the worn part only, when the wider part is forced into the resulting narrow path, the saw will stick and break, hence the importance of using all the blade.

Hacksaws are supplied in coarse and fine grades.

Coarse blades may be used to advantage on any broad surface where a good number of teeth may cut together, but if a thin edge is presented to the large teeth, they dig in and break.

Fig. 9 illustrates what happens when a coarse blade is cutting a thin edge compared to a fine blade.

It is always advisable, where possible, to cut across the widest part of the material.

Coarse blades are always used to cut soft metal, such as brass, aluminium, etc.

Fine blades are used on thin materials and on steels such as cast steel.

Brass causes the saw to become hot very quickly and should be sawn at a slower speed than other metals.

Hard steels also must be sawn at a slower speed than mild steel. Sometimes when sawing hard steel, the saw ceases to cut and begins to slip. This may be because of a hard spot in the steel, but is more probably because some of

Fig. 8

the hard steel from the blade has been rubbed into the work and is too hard to be cut. In this case, the saw should be started in a new place, preferably with a new saw blade.

The tightness of the blade in the hacksaw frame is another point to be considered. Finger tightness of the wing nut is quite sufficient to hold the blade rigid.

Apprentices may be seen holding the wing nut in the vice and turning the frame to tighten it. This is bad workmanship and ignorance. The result is, to bend the frame

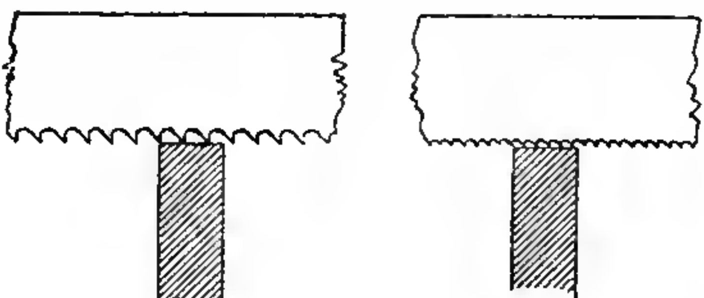


Fig. 9

and spoil the nut without any gain, for if you are a normally strong person you can tighten quite sufficiently by hand.

If the handle of your hacksaw frame is loose or bent, you are sure to break the blade.

If a deep cut is to be taken, the top of the frame may foul the work. In this case, the blade may be fastened in the

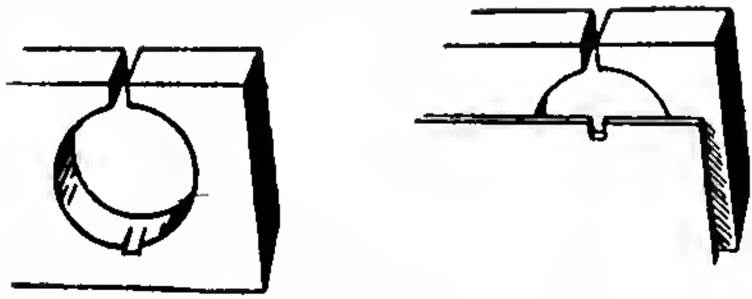


Fig. 10

frame, so that the frame passes clear down the side of the work. To make this possible, all hacksaw frames are so made that the handle and the bolt and nut at the other end may be turned at ninety degrees to the usual position.

Very often you will have to cut into a hole. The beginner usually breaks into the hole and marks it (Fig. 10).

It is wise to clamp a piece of steel across, then any mark which is made on the steel does not matter.

Do not attempt to start a new blade in a cut made by a saw which has been used. The new blade is wider and will stick and break. If you remember all you have read, if the blade is firm, the handle true, and frame and blade on one plane, there is no reason why you should not master the use of a hacksaw in a very short time.

CHAPTER IV

THE RULE

THE engineer's rule is such a simple article that at first it may seem absurd to devote a chapter to it, but what is easy to the man who knows, to the man who does not know may seem profound, and in my experience I have found that few artisans use the instrument to its full capacity. Since engineering is largely a matter of having a thing of the right shape, size and material in the right place at the right time, size is important.

Bench fitters use rules which are generally twelve inches long. They are divided into twelve parts, each part is, therefore, one inch long.

These inches are further subdivided into various numbers, the most useful being as follows :—

Into eight parts, each of which measures one-eighth of an inch.

Into sixteen parts, each of which measures one-sixteenth of an inch.

Into thirty-two parts, each of which measures one-thirty-second of an inch, and so on by sixty-four, by ten, by twenty, by fifty and by one hundred parts.

If an inch is divided into ten, each part is called one-tenth.

If an inch is divided into twenty, each part is called one-twentieth.

The usual fractional dimensions used by engineers are those which may be divided into sixty-fourths, one-eighths, one-sixteenths, etc.

If you will examine a rule you will see that it is easy to measure inches and fractions, such as $1\frac{1}{2}$ in., $2\frac{5}{16}$ in., or 3 in.

Sometimes, however, it is necessary to measure in decimal dimensions, such as 1.620 in. This generally throws a beginner

into confusion which a little more knowledge will dispel.

Since rule measurement can only be approximate, we use the nearest dimensions on the rule to the size we require.

One point six twenty (1.620) = one inch, six-tenths of an inch, and two hundredths of an inch.

Now 2/100 = 1/50 and as 1/50 divisions are marked on the rule, we may measure as in Fig. 11.

Similarly, it should be remembered that one-twentieth of an inch = .050 in., or fifty thousandths of an inch. Thus,

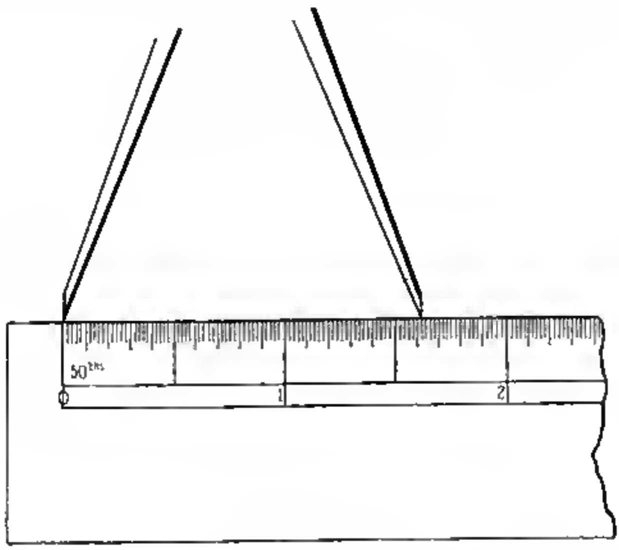


Fig. 11

if a measurement of 4.350 in. is required, this also may be directly measured.

The decimal equivalent of fractional sizes 1/64 in., 1/32 in., 3/64 in., up to 1 in. should be memorised by the student. A mastery of these conversions will well repay the little trouble required.

Now get a rule and practise marking off dimensions and you will be surprised in what a short time you become expert.

It is always better to tell people to do something rather than not to do something, but as there are so many little " don'ts" in engineering which are costly to learn, they must constantly be pointed out.

If your rule is a good make of 12-in. variety, the edge is straight enough for use to compare surfaces for flatness, so long as you treat it fairly.

If you are measuring between lines marked on work, then start measuring from a line on your rule and not from the edge, which becomes worn in time and incorrect.

If you are measuring between holes of the same size, it is easier to measure from the edge of one hole to the edge of the next (Fig. 12).

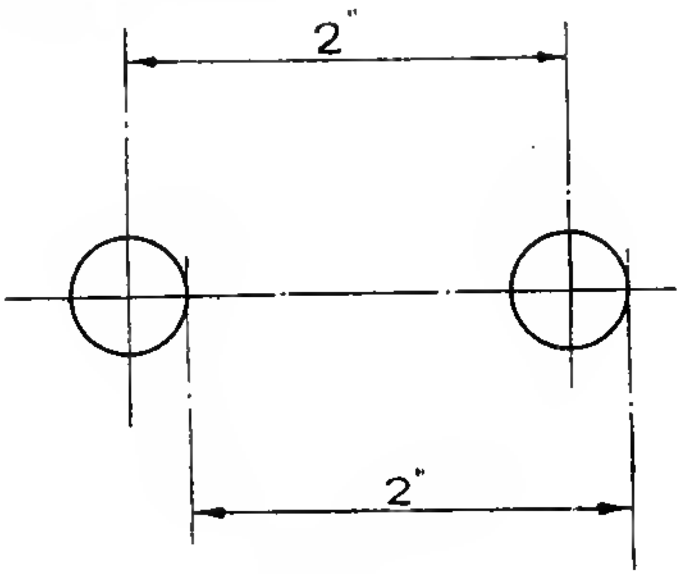


Fig. 12

When you have several dimensions to mark in line *do not* mark a dimension, move the rule and mark another dimension, but keep the rule in the same place until the whole series of sizes is marked. Failure to do this will result in accumulation of errors, so that the last mark may well be as much as 1/32 in. out of place.

If you have any common sense you will keep the rule away from water and acid, also hot steel, and see that you do not strike the edges against hard materials.

The size of your work begins from your rule; look after it.

CHAPTER V

SMALL TOOLS

The rule is only one of the many small tools, all of which deserve mention, for if a workman's small tools are in good condition, he begins his job with a much better chance of success than if they are in bad condition.

We will begin with the scriber (Fig. 13).

Scribers made by dependable firms are already of the correct hardness, but when the point becomes blunt through use, the scriber has to be sharpened.

In the sketch "A," Fig. 14, a scriber is shown ground incorrectly. The point is so thin that as soon as it is pressed against the steel it will bend or break.

Another incorrect method is shown at "B" where the scriber point is ground so that it is impossible to get it close to a rule, and the angle is too great to allow a sharp point.

At "C" is shown the correct angle.

The point is strong enough for use and yet sharp enough to cut steel and lie close against the rule.

Scribers are often made in workshops from cast steel, and instructions for hardening and tempering them will be given later. The scriber is sharpened by holding against a grindstone and revolved by means of the fingers. Personally, I prefer to sharpen them on the side of the stone, although this is a more dangerous practice than sharpening in front on the rest, but the result is better. Care must be taken to see that the heat caused by friction with the stone does not heat the scriber enough to spoil it. The heat must be kept down by constantly dipping the scriber in water.

After grinding and having taken care that the point is in the centre of the scriber, a touch on an oil stone will lengthen its life and assist it to cut.

If it is required to mark a bright surface, cover the surface first with copper sulphate, allow the sulphate to dry and the lines on the coppered surface may them be clearly marked.

Fig. 13

To make copper sulphate proceed as follows :—

Take some water (preferably distilled water) and dissolve in it as much copper sulphate as possible. To this add a few drops of sulphuric acid, four or five drops to half a pint of water is sufficient.

The surface to be coppered must be clean and free from grease and the solution applied by means of a clean rag or cotton waste.

When marking thin steel plate it is unnecessary to apply any marking compound, as the scriber will cut the black oxidised surface and show bright lines quite clearly.

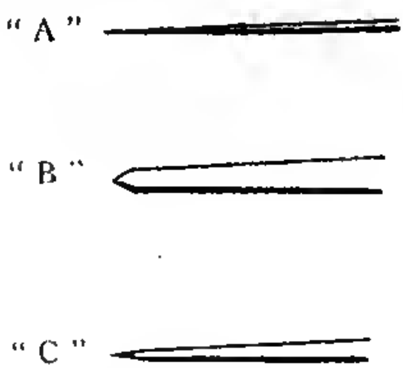


Fig. 14

It is bad practice to mark on aluminium with a scriber, especially if a bend is to take place where the line is drawn. A brass scriber must be used.

Familiarity with different metals will come only through contact, and it is assumed that the student is able to see for himself the different metals mentioned here.

Cast iron is usually whitewashed or chalked before being marked. As the surface is full of sand, you will find your scriber wearing away very quickly when engaged on this work.

To describe circles, and accurately check distances between lines and centre-punch marks, dividers are used (Fig. 15).

All notes on scribers must be observed when sharpening this instrument. When taking a distance on a scale by dividers, do not hold the instrument vertically on the hard scale and press or you will break off the point you have taken such pains to sharpen.

Incline the dividers at a slight angle or if great accuracy is being attempted, only press very lightly.

Hold the dividers by the knurled pin provided.

If a hole is to be drilled or a circle described, a centre punch is used to mark the place (Fig. 16).

Only a small mark is made when the purpose is to mark the centre of a circle to be described by dividers, but if this hole is to be drilled later it must be enlarged before drilling.

The centre-punch mark must be deep enough for the drill point to enter into it.

See that the point is sharp enough to make a deep mark and yet strong enough to withstand the blow against the steel.

It is very important that the point is ground as accurately in the centre of the punch as possible, the drill will otherwise "wander" as indicated (Fig. 17).

If it is desired to move a punch mark to any direction, the punch may be inclined and then struck with the hammer, but the final blow must be made with the punch in a vertical position.

The fitter's hammer is usually of the kind called a ball pane hammer (Fig. 18).

Hammers are made in different weights for different kinds of work.

A hammer of half a pound in weight will be found the most suitable for all-round use, although in the blacksmith's shop it would be much too light and the tinsmith would find it too heavy for much of his work.

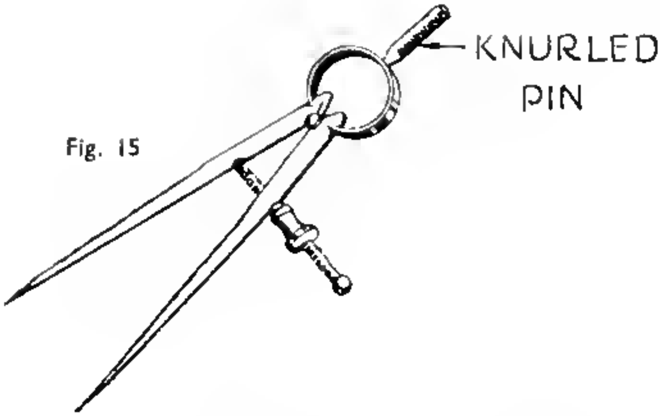


Fig. 15

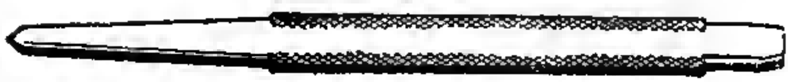


Fig. 16

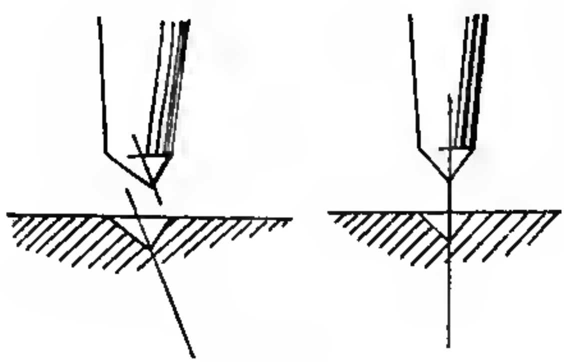
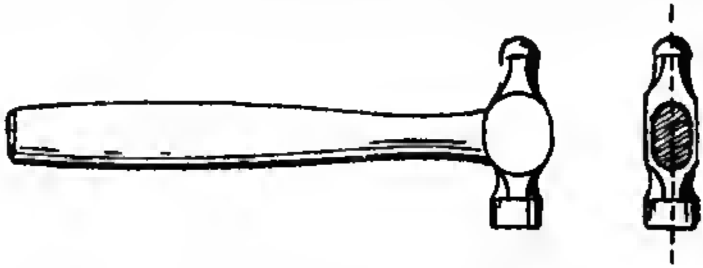


Fig. 17

You will be wise if you use the same hammer always, then your hand will become familiar with the character of the shaft and you will gradually be able to strike steel without



FITTERS HAMMER

Fig. 18

marking it, and also hit your centre punch without hitting your fingers.

Grip the hammer near the end of the shaft and if you are striking a chisel, look at the cutting edge and not at the head you are striking. It is a mistake to grip the hammer too hard, it should be swung easily.

The ball end is used for riveting.

Hammer handles are generally made of some durable resilient wood, such as ash or hickory.

The handle is so fixed that a line passing through its widest part would also pass through the centre of the hammer, as indicated by the dotted line shown in the sketch. If this is not so, the hammer has a tendency to twist in the hand when a blow is struck, and it is much more difficult to strike metal without marking the metal.

The wedge is generally of hard wood, but steel wedges may be fixed quite successfully.

If the hammer face is marked, it may be lightly ground on a grindstone and then cleaned well with emery cloth.

Scribers, centre punches, dividers and hammers are all made of cast steel and are, therefore, liable to break if ill treated. If, for instance, you strike a hardened piece of steel with a hammer, you will probably break either the hammer or the steel you strike.

Hammer faces break off in chips, which travel at considerable speed and have the sharpness of a razor, from which remark you will see that you must not strike hard steel with a hammer nor strike two hammers together.

The usual result of such an action is bad cuts on the arms and people have been blinded by doing this.

The top of your centre punch is soft, so you may strike it as hard as you like, if you have the confidence.

The proper name for the next small tool to be mentioned is hermaphrodite calliper, but in English idiom it is known as " Jennys " or " Oddlegs." The latter name to my mind is the most applicable.

As may be seen in the sketch (Fig. 19), it consists of a scriber fastened to one leg, while the other leg is bent slightly to guide the scriber any desired distance from the edge of the metal.

The required distance is first taken from a rule, putting the bent leg on the end of the rule and stretching the other leg until the required length is reached. This length may then be transferred to the work.

The point must be kept sharp like a scriber.

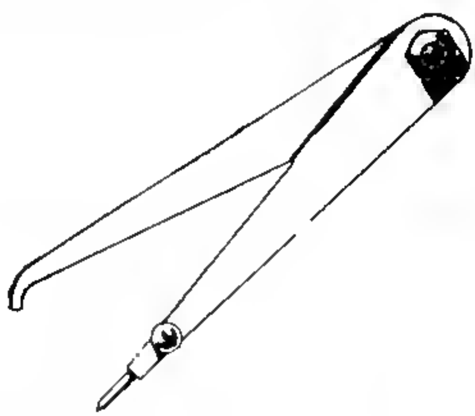


Fig. 19

Outside Callipers

The outside calliper, although much replaced nowadays by the micrometer, is still a very useful tool for measuring cylinders, but some practice and skill in " feel " are required

before good measurements may be taken. In use, the calliper must be kept square with the work and not inclined at an angle. When measuring inside cylinders make sure the calliper measurement is taken on the centre line of the hole.

Outside and inside callipers are shown in Fig. 20.

They are first opened to the approximate measurement and then struck lightly on the wooden bench at " A " to close slightly or at " B " to open slightly.

See that the nut is of the right tension, neither too tight nor too slack.

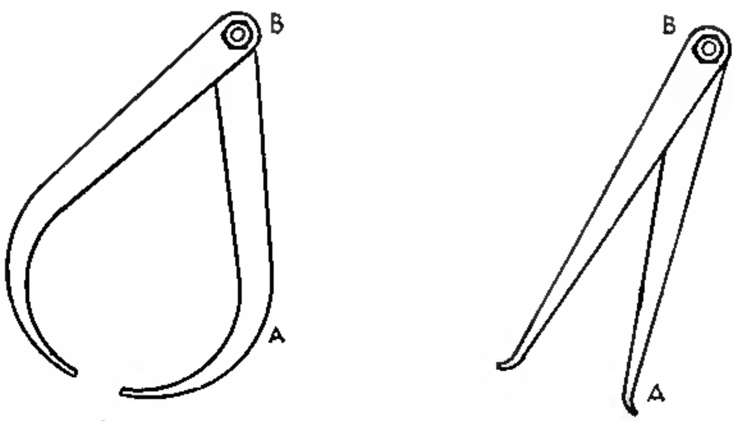


Fig. 20

On page 7 (Fig. 6) is drawn an engineer's square. This is your standard for making a right angle.

You may test it by comparison with a master square or approximately by drawing a line on a coppered surface, then reversing the square and drawing another line close to it. If the edge against which the square is being held is straight, then the two lines drawn should be parallel; if they are not, your square is incorrect.

The square should have a burr slot to clear the burr caused by the file.

The square must be held at right angles to the edge being examined; if you incline the square you will get a false indication of the truth of the surface under examination.

Regularly check the square, not only for angular accuracy,

but to make sure there are no burrs on it and that the blade is straight.

Some squares are adjustable, so that they may be used in places where a fixed square will not enter. (Fig. 21.)

They may also be used to measure depths and for marking a distance with a scriber.

The sliding blade is usually in the form of a small scale.

Make sure the nut is tight before use.

The importance of keeping scribers, centre punches and dividers sharpened and properly ground may be mentioned

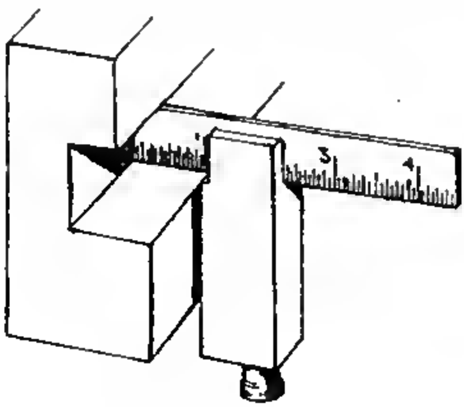


Fig. 21

again, as so much work is spoiled through first being indistinctly marked to size.

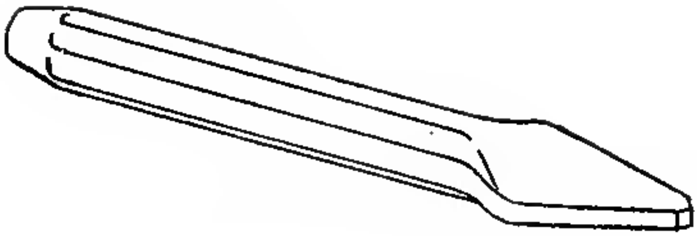
It is my serious opinion that an enormous amount of scrap in workshops is caused through incorrect and faint marking. Mark the shape of your job clearly and as accurately as possible and you will save yourself much failure and embarrassment.

Chisels

When it is required to remove more metal than can economically be done by a file, a chisel is employed. Chisels are made from cast steel. The steel is usually hexagon in section to assist the grip. The blacksmith beats out the chisel from the hexagonal cast-steel bar to whatever shape required.

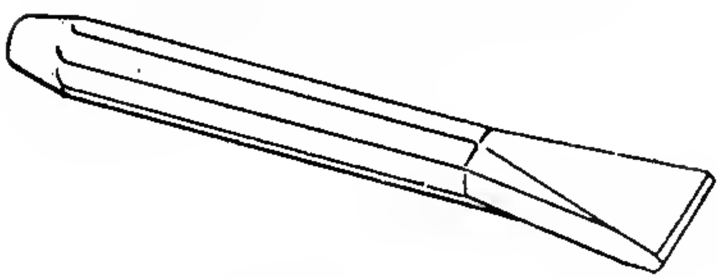
It is then hardened and tempered and chamfered on the top. The purpose of the chamfer is to prevent ugly burrs forming over the end after use. As will be seen from Fig. 22 various types of chisels are used for different purposes.

The ordinary flat chisel is used for work of a general nature, such as removing surplus metal. If it is required to cut a narrow keyway, say in a steel shaft, then a cross-cut chisel would be most suitable. Cross-cut chisels are also used when it is necessary to remove a considerable amount of metal over a large area. Grooves are first cut into the face by means of the cross cut, and then the flat chisel is employed to cut between the grooves. Another chisel in common use is the diamond chisel, commonly used for cutting oil grooves and weakening thin plates so that they may easily be broken. The cutting angle of a chisel is not the same for all metals. Naturally the harder the material to be cut the stronger must the cutting edge of the chisel be. For cast steel the included angle will be about 65 deg., for cast iron 55 deg., for mild steel 50 deg., and for brass and soft alloys 40 deg. Using a hammer and chisel, like using a file, requires some practice. First be sure that the chisel is sharp and ground to approximately the proper angle. Watch the *edge* of the chisel when cutting and *not* the end you are striking. Endeavour to cut in such a way that you are removing an angular corner all the time. It is a mistake to try to remove too much metal in one cut. Start the chisel lightly and increase the blows to normal cutting strength as the chisel edge takes hold. Chisels have fallen out of use to some degree because of the introduction of improved machine tools. Nevertheless, a fitter should have the ability to use them if called upon to do so.



— CROSS-CUT CHISEL —

— DIAMOND-POINT CHISEL —



— FLAT CHISEL —

Fig. 22

CHAPTER VI

MARKING OUT

In this chapter we may begin to discuss actual work, assuming that now you will know a hammer if you see one, and can select dividers from oddlegs.

To what accuracy may distances be marked by means of rule, scriber and square?

If the distances to be marked do not exceed the length of the rule, then your distances should not be .010 more or less than you intend them to be, provided your scriber and centre punch are sharp and ground approximately with the point in the centre. The usual practice when marking out on mild-steel plate is first to make square two edges of the work or make one edge straight, and draw a line near the rough vertical edge at 90 deg. to the straight edge, so that you have two datum lines. If the vertical line you require must be longer than your square, you can erect it by measurement if you remember that a triangle having one side three units long, one four and one five must be a right angle (Fig. 23).

Once the base is prepared and a vertical line is erected, you may measure the distances required. An example is given (Fig. 24).

First prepare the straight edge by filing and comparing against the light with your 12-in. scale, then with your square and scriber erect a perpendicular. Next take oddlegs and mark off a line 1 in. from the bottom for the two bottom holes. Then take $1\frac{1}{2}$ in. in your oddlegs and draw a line from which your $\frac{1}{2}$ in. radius at "A" must be described. Then take 4 in. by oddlegs and mark the line for your upper radius at "B" and so on. Now work from the vertical line.

Placing the 1-in. line and not the edge of the rule on the vertical line and parallel with the top line already scribed, mark the $1\frac{3}{4}$ in. at "B."

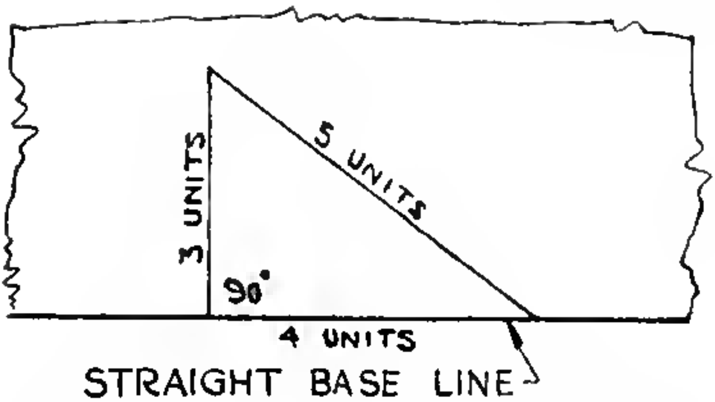


Fig. 23

Next, place the 1-in. line on your rule on the bottom line and, without moving the scale, mark off the required distances at " C " and " D " and at 8 in. from vertical line or 9 in. on your rule and back ½ in. for position of point " A," all without moving the rule, then with your square and scriber lengthen and clarify your vertical lines, centre-punch lightly, describe your radii with dividers and join the outside lines.

If the steel is bright or has a machined surface, you will have to put copper sulphate on first of course, but if the steel is black, then no preparation is required.

You can mark out more accurately on a bright coppered

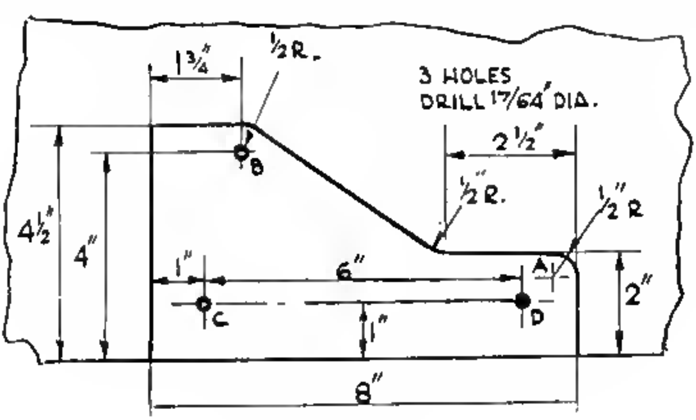


Fig. 24

surface than on a rough black surface, so if real accuracy is necessary get the steel machined first.

Sometimes it is necessary to describe a radius larger than may be drawn by your dividers. In that case "trammels" are used, consisting of a bar having two movable scriber points (Fig. 25).

Special care must be taken when using the centre punch to see that the mark is made where the lines join. It is care well repaid to examine the mark with a magnifying glass when it is very small and then carefully "draw" the mark whichever way it should go. Reverting back to the example, the centre-punch marks used to hold the divider point for the purpose of drawing the radius must be as small as possible, but the punch marks through which a drill has to pass must

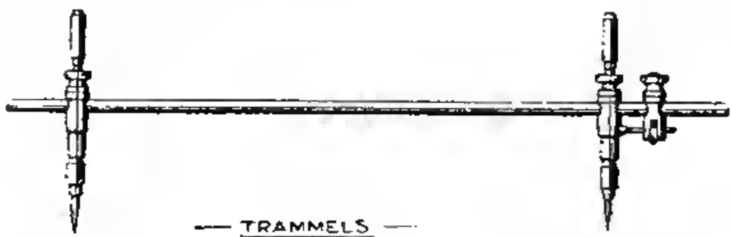


Fig. 25

be enlarged when you are satisfied that they are in the correct position.

Consider that you are asked to mark out a square on a round bar, then you will have to use your "V" blocks and "surface gauge" (Fig. 26).

Clamp the round piece in the "V" block and using your "surface gauge" find the centre by scribing a line which appears in the centre to you, then turn the round piece 180 deg. in the "V" block and scribe the same line again.

It will then be easy to adjust the scriber on centre. See Fig. 27.

Clamp your scale vertically against an angle plate with your toolmaker's clamp so that a norminal size such as 1 in., $\frac{1}{2}$ in., or $\frac{1}{4}$ in., whichever is most easily attained, comes opposite your scriber point, and measure half the width of

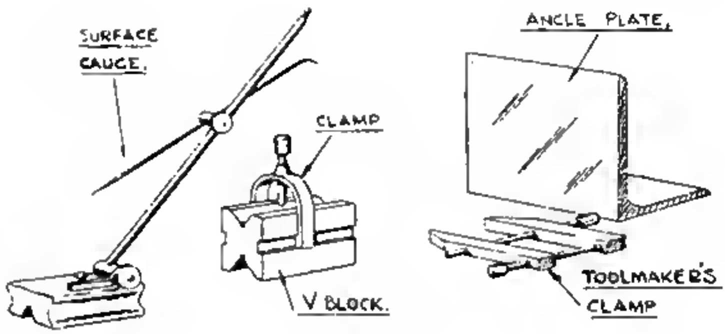


Fig. 26.

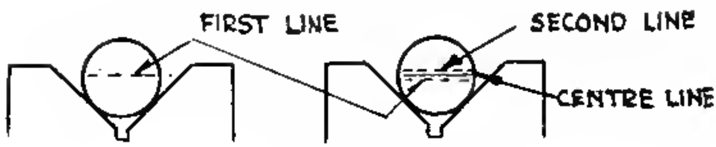


Fig. 27

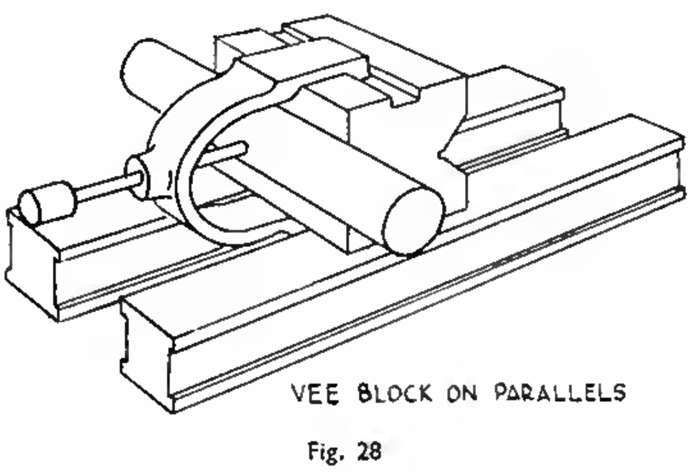
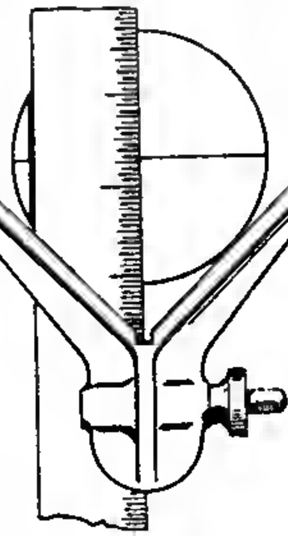


Fig. 28

your square up and down from the centre line, transferring the distance from the scale to the work by means of the surface gauge. Now put your "V" block on "parallel strips" (Fig. 28). Turn it at 90 deg. putting the clamp between the parallels and repeat as at first.

A " centre square " (Fig. 29) is a useful article for finding the centre of a round bar by drawing two lines at right angles, and is to be found in that combination of tools called a



CENTRE SQUARE

Fig. 29

" combination set " which comprises a square, a centre square and a protractor.

The protractor is an instrument used for measuring and marking out angles other than 90 deg.

The protractor in a combination set is marked in degrees, but a much better protractor is the one with a Vernier reading whereby it is possible to read to 5 minutes or one-twelfth of a degree. This will be explained later.

The best kind of protractor has an extension for the purpose of measuring very small angles which is difficult on an

ordinary instrument (Fig. 30). A protractor of this type is shown with an angle of 3 deg. being used to check work.

A very common problem to the fitter is to mark out a number of holes equally spaced on a circle of a given diameter generally called the pitch-circle diameter (Fig. 31).

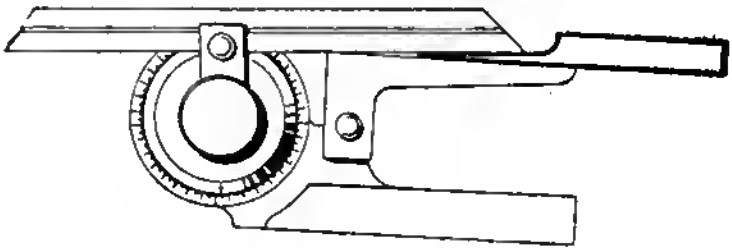


Fig. 30

If there are six holes to be marked on a pitch circle, it will be found that the radius of the circle will divide it into six like this.

If each division is bisected again, we get 12 divisions as shown on the right above.

It is quite easy to divide into three, of course, or into four by simply drawing a line through the centre and bisecting, but supposing that it is required to drill, say, ten holes equally

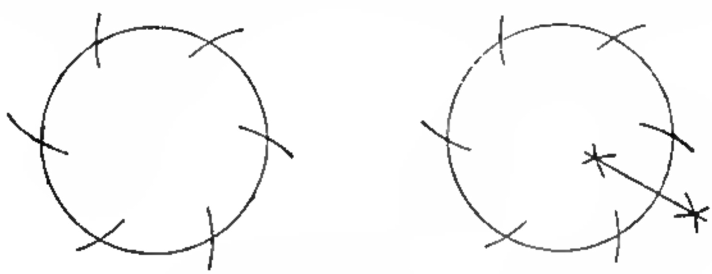


Fig. 31

spaced on a given pitch-circle diameter. First find the angle by dividing 360 by the number of spaces: 360 divided by 10 = 36.

Divide this by 2 = 18.

Now look in a table of trigonometrical ratios without being frightened by the name and see what is the " sine " of 18 deg.

You can do this quite easily even if you do not understand trigonometry. Multiply this number by the radius and the answer by 2, and that will give you the distance to set your dividers to step round the circle ten times.

Here is an example :—

It is required to mark out 15 holes on a circle of 20 in. diameter, or 10 in. radius.

First find the angle; 360 deg. divided by 15 = 24 deg.

Divide by 2 = 12 deg.

Now look in your trigonometrical table and see that the "sine" of 12 deg. is .309. Multiply this number by the radius radius = 10 in., therefore .309 in. multiplied by 10 in. = 3.09 in., and again multiply by 2 = 6.18 in., and that is the distance to set your dividers or trammels in this case.

When you begin to drill into a centre-punch mark, the drill nearly always "wanders" out of its true position, therefore some precaution must be taken to see that this does not happen, or to correct it when it does happen.

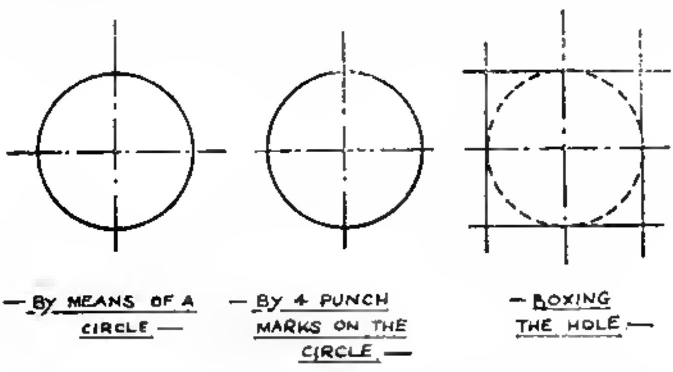


Fig. 32

Once a drill has cut a mark its full diameter it will not wander given fair treatment or unless the hole is very deep, so if the drill is known to be cutting in the position of your centre punch when it has just begun to cut its full diameter, you may confidently proceed to drill.

To make sure this is so, three methods are in general use.

First, describe a circle with your punch mark as the centre and see that the drill cuts the line equally, drilling

a little, examining the mark and drawing over with a centre punch whichever way it must go (Fig. 32).

In the second method, four small punch marks are made on the lines which must be cut in half as illustrated if the drill is drilling correctly.

The last method is used when the highest degree of accuracy which may be expected from hand work is required. This is known as "boxing the hole." The hole is enclosed by four lines exactly the whole diameter apart. These lines are marked

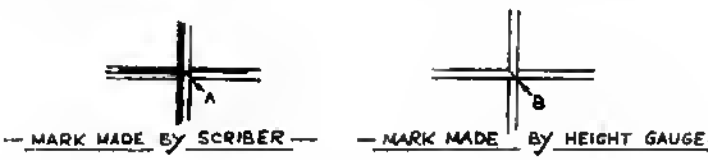


Fig. 33

by means of a "vernier height gauge," which will be mentioned and explained in due course.

To anybody who has carefully observed the marks made by the "bit" of a height gauge (Fig. 34) and the mark made by a scriber, this difference will be obvious.

In the case of the scriber the centre mark will be in the centre at "A," but in the case of a height gauge the centre will be in a position at "B" in one corner (Fig. 33).

If this difference is ignored, you will make small errors when using your height gauge for marking out

If four holes are to be marked on a square, it is easy to check the diagonal distances with dividers. If your marking is correct, then the distances will be the same.

Although instructions for using a vernier height gauge (Fig. 34) have not yet been given, it is not out of place to state here that a man who has a knowledge of trigonometry and can use a height gauge, has a great advantage over a man who is restricted to rule and surface gauge.

Holes may be marked with ease and accuracy that would otherwise be difficult or impossible to mark successfully by other methods.

The angle plate (Fig. 26, page 29), should have the two faces at right angles and the two edges also perpendicular

to the base, it is then often possible to turn the angle plate through 90 deg. without disturbing the job, which has previously been secured.

Since, when marking out, errors are invariably made, work should be compared with the drawing dimensions again after marking and carefully checked over.

Most marking out is done on a flat smooth surface plate so this may now be described.

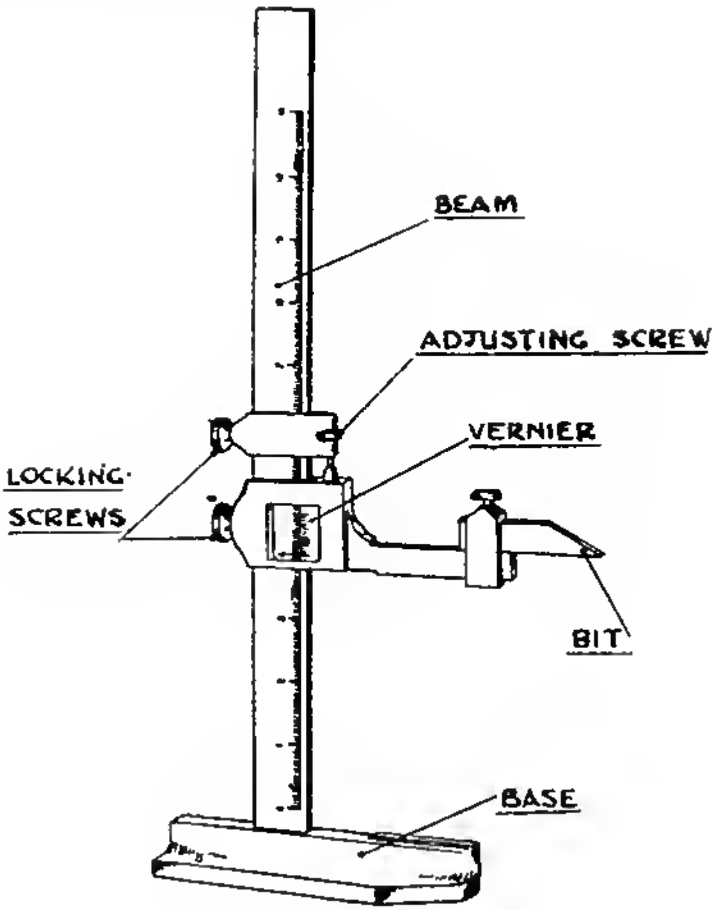


Fig. 34

CHAPTER VII

SURFACE PLATES

Surface plates are usually made of a good quality cast iron. They are ribbed to give them strength to resist warp and must be light enough for manipulation.

In the sketch (Fig. 35) a typical surface plate is shown with the ribs clearly indicated.

Surface plates are generally supplied with handles so that they may be lifted and placed on other surfaces.

It will be noticed that the surface plate in the drawing has three feet, the purpose of this is to prevent rocking, just in the same way a photographer's tripod has three feet, so that it may stand firmly on uneven ground.

Large plates, however, have four feet to support their greater weight, and must be firmly secured.

The working face of the plate may be finished smooth and true by scraping, lapping or machining. The simplest method and one which has been proved very satisfactory is the scraping method.

It is true that a very good surface may be obtained on a surface plate by machining only, but the surface is always considerably improved by scraping. It has two main uses.

First, by the aid of marking compound it may be used for testing the degree of flatness of other surfaces.

Secondly, it is used as a datum plane when marking out.

You may wonder how the first surface plate was made perfectly flat if there was no other flat surface plate with which to compare it. This will be explained later.

The main thing to be understood at this stage is that most of your marking out must be done on a surface plate which you can confidently believe has a surface in one true plane.

The more you know about a surface plate, the more con-

fident will be your use of it, your work will take on some of that accuracy which comes from confidence, and the more benefit it will be to you.

It has been stated that surface plates are made of cast iron; now it must be explained that cast iron which is new is said to be in the "green" condition.

First, the hot liquid cast iron is run into a mould of the same shape as a surface plate. When the cast iron begins to cool, stresses and strains are set up in the metal and some period of time must elapse before these strains disappear and the surface plate ceases to twist and bend. Of course, these changes in the shape of the plate are not visible to the eye, but may easily be detected by fine measuring instruments.

The usual procedure is to take a rough cut by machine all over the plate, that is, the top and sides and the bottom feet.

The plate is then left outside in the open air for a period lasting up to six months to "weather." After this period, it has settled sufficiently internally to be finished to a high degree of accuracy, without the removal of metal, causing the plate to twist or warp unduly.

The plate is then finished as accurately as possible by machine and sent to the fitter to be scraped or lapped.

The four edges are finished straight and square to each other and the under surface machined for about one inch deep for the purpose of clamping work to the plate.

A wooden cover should be provided to protect the plate from injury, corrosion or rust.

When not in use, cover the plate with a film of oil and wash this off with cotton waste and paraffin when required.

If you try to mark out on an oily surface, you will find your surface gauge and height gauge sticking to the plate in some places and slipping in others and your marking will suffer accordingly.

Files, hot steel, metal shavings, lapping paste or grit of any kind are injurious to surface plates. Keep these things away from a surface plate or your work will suffer and your employer will not be pleased.

The usual practice in good class engineering shops and

tool rooms is to scrape the plate after machining, so details of a scraper will now be given.

How to Make a Scraper

I have never bought a scraper which has given me satisfaction, but I have made some very good ones out of old files.

First grind all the teeth marks from the end of the file for about one and a half inches, taking care not to get the file too hot; it must be constantly dipped in water while the grinding is taking place.

Be sure no trace of a file tooth remains as in that place a crack will develop when hardening and your work will be wasted.

Now grind it roughly to shape, then take the scraper to

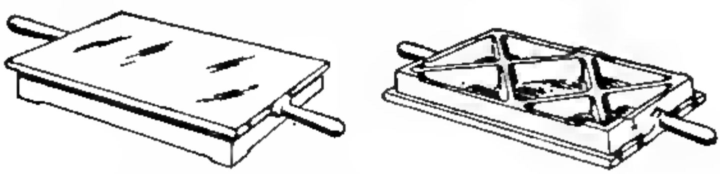


Fig. 35

the hardening shop and bring it slowly, preferably by gas flame or furnace, to red heat, then plunge it in water. When it is quite cold clean the end using emery cloth and again apply the flame near the end when colours will be seen moving along the polished surface. When a "straw colour" reaches the end, plunge it once more in water and your scraper will be hardened and tempered and ready for sharpening.

Keep it away from the grindstone unless you have a very fine stone, and sharpen it to the shape shown in the sketch by using oil stones. First rough to clean the surface and then smooth to give it a fine close cutting edge.

If the scraper is weakened by grinding about 2½ in. from the end, as shown, a slight "spring" will be achieved when in use, which helps to prevent scratching.

It is unnecessary to make two scrapers, as the roughing

scraper may easily be stoned into the shape for finishing when the work is sufficiently advanced to warrant it.

If you can obtain a small piece of high speed or good tool steel and make a holder, you will find you have a scraper of the very best quality, but let a man whose job is hardening, harden and temper it for you.

A scraper only cuts on the forward stroke. The beginner usually cuts too little at a time, so don't be afraid to apply pressure, and think in your mind all the time that you are shearing the metal off and not pushing it off.

Cut in different directions so as to break up the surface. If you cut all in one direction, you will find the work harder, and the finish will be inferior.

If this chapter has been so far understood, all you need now is practice, and after reading the next chapter you may begin to originate your own surface plate.

CHAPTER VIII

HOW TO ORIGINATE A SURFACE PLATE

SURFACE plates which are true and flat can be made without the help of other plates which are known to be flat, provided there are three plates available.

When the three plates have been rough cut and "weathered" they are machined to as great an accuracy as possible.

All machine marks are then scraped out and the plates stamped No. 1, No. 2 and No. 3. The stamping is done on the side of the plate, and not on the surface.

Then proceed as follows :—

First No. 1 plate is covered thinly with some marking compound, such as prussian blue, lamp black or red lead.

Care in the preparation of the marking compound will help in the attainment of accurate marking.

Prussian blue is supplied in tubes and is ready for immediate use, but lamp black and red lead must be mixed with oil to the consistency of paste.

Patience is required to get the red lead to mix with oil.

It must be well stirred and kneaded.

The apprentice using red lead for the first time seldom puts as much red lead on the work as he puts on himself, so a hint on how to apply red lead to the work may here be given to advantage.

Take a 6-in. square piece of coarse sacking and in this place a ball of cotton waste. Now close up the edges of the sacking and secure with several turns of twine and you will have something like Fig. 36.

The bag may then be held by the top bound portion, and the bottom, after being well pressed into the marking compound, may be applied to the work.

Now take plate No. 1 and cover it with the marking com-

pound, the result should *not* be an oily surface, the marking compound should merely dull the surface. Do not put too much marking compound on the plate, the thinner you can apply it the more accurate will be the result.

Having then covered plate No. 1 to your satisfaction, place it on plate No. 2 and rub them both together, only making a small movement during the rubbing process. Take them apart and you will see your marking compound showing distinctly on all the high spots on plate No. 2.

Scrape these spots off with your roughing scraper, holding the scraper at about 20 deg. to the surface of the plate. Clean plate No. 2 with a brush, not with your hand, and repeat the marking and scraping process until, when the plates are taken apart, the marking shows a good average contact over plate No. 2.

Now, as plate No. 2 fits plate No. 1, it will be the reverse shape.

Imagine, for instance, that plate No. 1 is convex.

Then plate No. 2 will be concave.

Bear this fact in mind and, putting No. 2 aside, scrape No. 3 to fit No. 1.

Now No. 2 and No. 3 will be the same shape, so now we put red lead on No. 2, rub No. 3 on it and scrape both.

The marking compound will be scraped off No. 3 and the black marks showing will be scraped off No. 2 until again the marking shows evenly over plate No. 3.

Plates No. 2 and No. 3 will now be truer planes than No. 1.

Take plate No. 1 and scrape it to fit plate No. 2.

Now No. 1 and No. 3 are both like No. 2 and may both be scraped together.

If this sequence is continued until all three plates, after being compared with each other, touch all over their surfaces, the plates can be assumed to be very near true planes.

When the plates begin to appear somewhere near this stage, use your finishing scraper and scrape them all, finally removing the metal from the plate which has the red lead on it. You will see on this plate small bright spots and if these are carefully removed, your work will take on a truer surface than that obtained by scraping the not so clearly defined

Fig. 36

red smudges. After each scraping operation and when all the markings have been removed, care must be taken to clean the plate thoroughly from all dust and dirt, preferably with a soft brush.

Keep the pad you use to cover the plate with marking compound on a clean piece of sheet tin, or in the receptacle holding the compound. If you put it on the bench, it will pick up dirt and grit which you will transfer to the plates and nasty scratches will result on the surface of your work.

Sharpen your scraper on a very smooth oil stone ; this will prolong its life, give it a keen cutting edge, and leave no scratches on the work.

Hold the handle of the scraper naturally in the right hand close to the body. The left hand should be on the top of the scraper near the end.

Cut slightly to the side, and not straight forward.

When sharpening a scraper, hold it vertically on the oil stone with your right hand on the bottom and your left hand on the top and draw it towards you at what you think is the right angle.

When sharpening the finishing scraper turn it over to get the angle equal on both sides, and finish off by

placing the sides flat on the stone and rubbing a few times. Inspect the edges and make sure they are sharp and not rounded.

If they are rounded, then practice sharpening until they are not.

There are many ways of finishing a scraped surface so as to make it pleasing to the eye, but they require more skill than can be attained in a short time. However, if the operator has cut in different directions, a good finish will automatically result.

It will probably take you a day or two before you can scrape with much skill, and some practice is required before you can sharpen your scraper properly, but I know that very good scraping can be done by an apprentice after practice, providing he takes care to observe that his scraper is sharpened to the right shape, held at right angle to the work and used in conjunction with his brains.

CHAPTER IX

THE MICROMETER

So far we have only dealt with the approximate measurements which it is possible to make with a rule. The micrometer (Fig. 37) is an instrument that can measure to a thousandth part of an inch, or even a ten-thousandth part of an inch.

This instrument may now be described in detail and instructions given for reading it accurately and using it properly.

If you turn a bolt in a nut it advances or recedes along the bolt.

Imagine the bolt has ten threads to the inch, then if you turn the bolt to the right for one complete turn, it will advance 1/10 or .1 in.

Now imagine the bolt head is divided into ten divisions. If the bolt is turned through a distance of one of these divisions and the nut is stationary, it will advance $1/10 \times 1/10 = 1/100$. The micrometer is based on this principle.

The spindle is the bolt of the micrometer and it is secured to the thimble.

The nut is fixed permanently inside the barrel.

Study the sketch and get this clear in your mind.

Now the bolt and nut have forty threads per inch, so that if the spindle (which is the bolt) is turned one complete revolution it will move a distance of 1/40 in. or .025 in.

It is easy to see when the spindle has turned one complete revolution, by the marking on the thimble.

The thimble is divided into twenty-five divisions, each division representing 1/25 of a complete turn.

As one complete turn = .025 in., one division will equal .025 in. divided by 25 = .001 in. or one-thousandth of an inch.

The barrel is marked at intervals of one-tenths, each tenth is divided into four, so each small mark = .025 in.

It has already been stated that one complete turn of the spindle = .025 in.

The marks on the barrel are only a guide to say how many times the thimble has been revolved.

Now to read the micrometer :—

First count the number of tenths visible on the barrel.

Next count the number of .025 in. divisions visible.

Add to this the number of thousandths on the sleeve which corresponds to the line on the barrel.

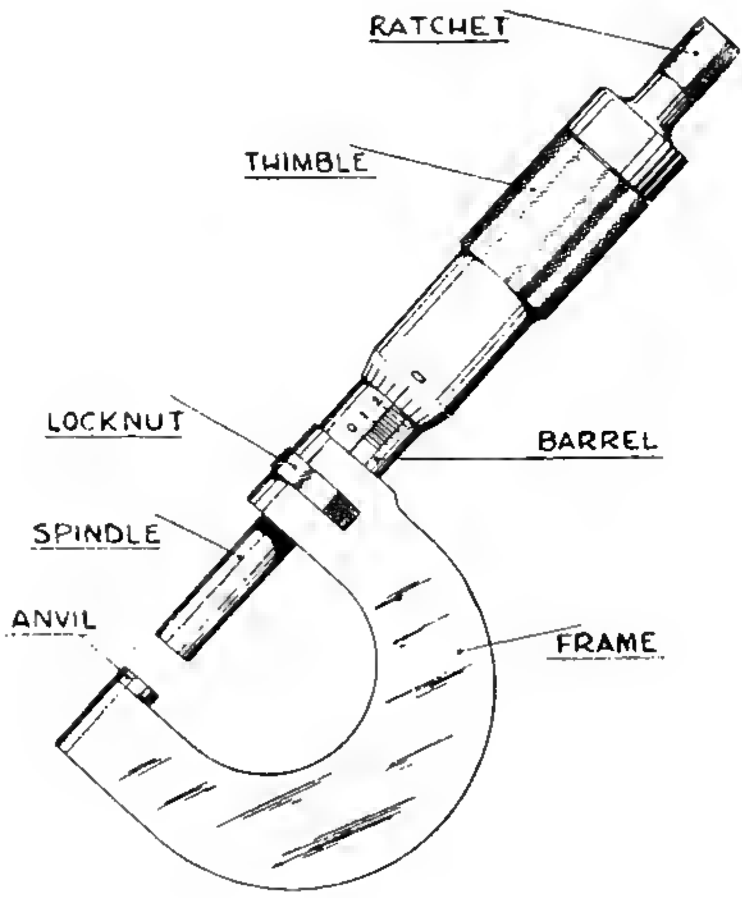


Fig. 37

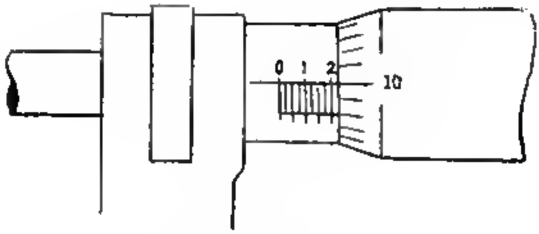


Fig. 38

Here is an example :—

Number of tenths visible = 2, that is — .2 in.

Number of .025 in. divisions visible = 1, that is .025 in.

Number of thousandths on the sleeve which corresponds = 10, that is .010, so that the reading is, .2 in. plus .025 in. plus .010 in. = .235 in. (Fig. 38).

If the resoning so far has been clearly understood, all that is required is practice.

Accurate reading of a micrometer depends a lot on " feel."

A beginner should use the ratchet at first until he understands the approximate pressure required to hold the article being measured. The worst error is to squeeze too tightly. This not only gives a false reading, but damages the fine thread on the spindle.

When the micrometer is closed the zero on the thimble should line up with the zero on the barrel, if this is not so, a false reading will result. To check this, lightly grip a piece of clean paper between the anvil and the spindle and withdraw it cleaning away any dirt which may be on the faces, then close the micrometer and see if the lines coincide.

If they do not, then the micrometer must be adjusted until they do.

Micrometers are adjusted in four principal ways :—

(1) By advancing the anvil by means of a screw.

(2) By turning the barrel by means of a special key.

(3) By advancing the nut farther into the barrel, also by means of a special key.

(4) By releasing the thimble from the spindle, turning the thimble until the lines coincide, and locking again.

It is not advisable, however, for a person who is not

accustomed to the micrometer straightway to begin adjusting it ; the wisest course is to ask some skilled man to do it for you.

A micrometer is a delicate instrument, and if a man has one of his own, you will seldom see him lending it to anyone else.

All fitters and machinists do not hold the micrometer in exactly the same way. The method shown in Fig. 39 is the one most commonly employed.

So far only the one-inch external micrometer has been shown, but micrometers are made which measure up to six inches.

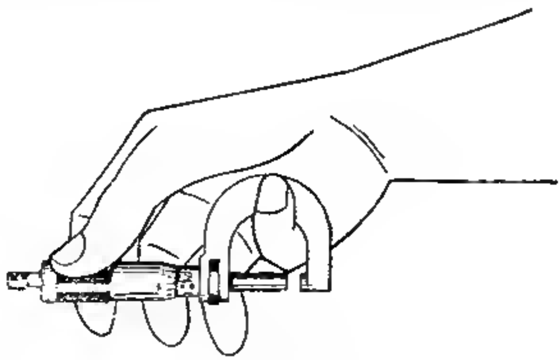


Fig. 39

Special micrometers measure even larger distances, but the method of reading is exactly the same.

Inside micrometers are used to measure inside cylinders and between faces.

Depth micrometers measure accurately the depth of steps and holes.

Thread micrometers (Fig. 40) measure the effective diameter of threads, but in all cases the principle of reading the micrometer is the same.

A word concerning thread micrometers. Any thread micrometer will only measure a certain range of threads depending on the pitch of the threads in the anvil, but each anvil will have a range of threads for which it can successfully be used. For example, one anvil may be used to measure

threads from thirty-two to forty per inch. The range of threads is usually marked on the micrometer.

The reason why one anvil will only cover a range of threads will be apparent if the following diagram is studied. (Fig. 41.)

Metric Micrometer

Metric micrometers measure to one-hundredth of a millimetre.

The pitch of the spindle screw is ½ mm., one revolution of the barrel, therefore, moves the spindle face ½ mm.

The bevelled edge of the thimble is graduated into fifty parts, each part representing one-fiftieth of half a millimetre, or one hundredth of a whole millimetre.

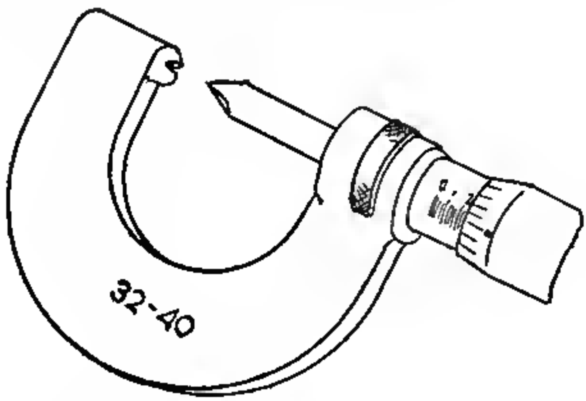


Fig. 40

The top row of lines on the barrel joining the axial line represent millimetres, every fifth line being numbered 5, 10, 15, to indicate 5 mm., 10 mm., 15 mm., etc.

The bottom row of lines represent half millimetres. An example is given in Fig. 42.

Whole mm. lines visible on barrel ...	=	6	=	6.00 mm.
Additional ½ mm. bottom lines visible	=	1	=	.50 mm.
Line on thimble which coincides with line on barrel	=	45	=	.45 mm.
		Reading	=	6.95 mm.

The micrometer is a subject which may be gone into in

much more detail regarding its construction and application to different uses, but this is a beginner's book and the purpose of the chapter is to teach him to read and use the instrument successfully, and become aware of the different applications to which it may be put.

Instructions for reading to one ten-thousandths part of an inch will be given in the next chapter.

Care of micrometer. It is a bad practice to keep it in your pocket as the dust from inside the pocket finds its way into the threads.

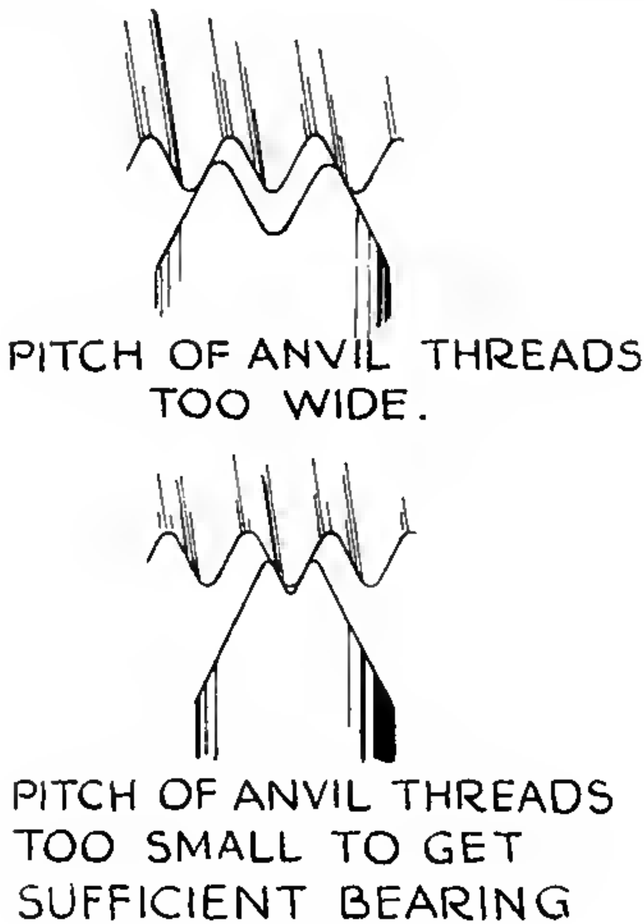


Fig. 41

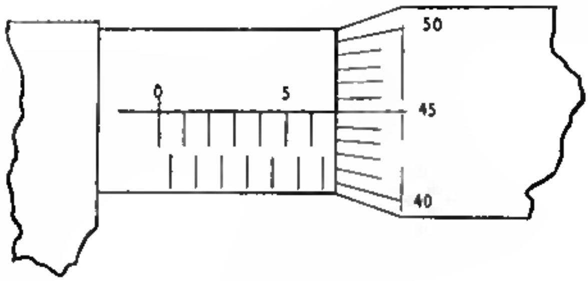


Fig. 42

Keep it away from any magnetic surface or it will constantly be picking up small particles of steel on the anvil and spindle.

Vaseline may be used to keep the threads lubricated.

Take the greatest care not to drop the instrument.

If you leave it lying on the bench it is sure to be injured, so keep it in the case provided, when not it use.

CHAPTER X

VERNIER CALLIPER

REMARKABLE accuracy as regards the fitting of one piece into another can be attained by skilled men on the bench and in the lathe machine, but in modern production it is not only necessary that a piece fits well into another piece, but that the " size " of the pieces also remain constant.

That is why micrometers and verniers have replaced the use of callipers. (Fig. 43.)

It is possible by means of a vernier calliper to measure to one-thousandth part of an inch.

Firstly, the principle on which the vernier is based may be explained :—

If an inch is divided into four parts, each part = $\frac{1}{4}$ in.—one-quarter of an inch.

If an inch is divided into five parts, each part = 1/5 in.—one-fifth of an inch.

In Figs. 44, 44*a*, 44*b* and 44*c*, an inch is divided into four parts and below it an inch is divided into five parts.

It will be seen that the difference between the top and bottom divisions is equal to .250 minus .2 = .050 in.

If the bottom scale is moved to the right so that the first line on " B " is opposite the first line on " A," then a distance of .050 in. will have been moved.

If the bottom scale is moved again until the second line on " B " is opposite the second line on " A," a distance of .1 in. will have been moved.

In Fig. 44*c* the third line on " B " is opposite the third line on " A " showing a distance of .150 in. has been moved. The vernier calliper is based on this principle.

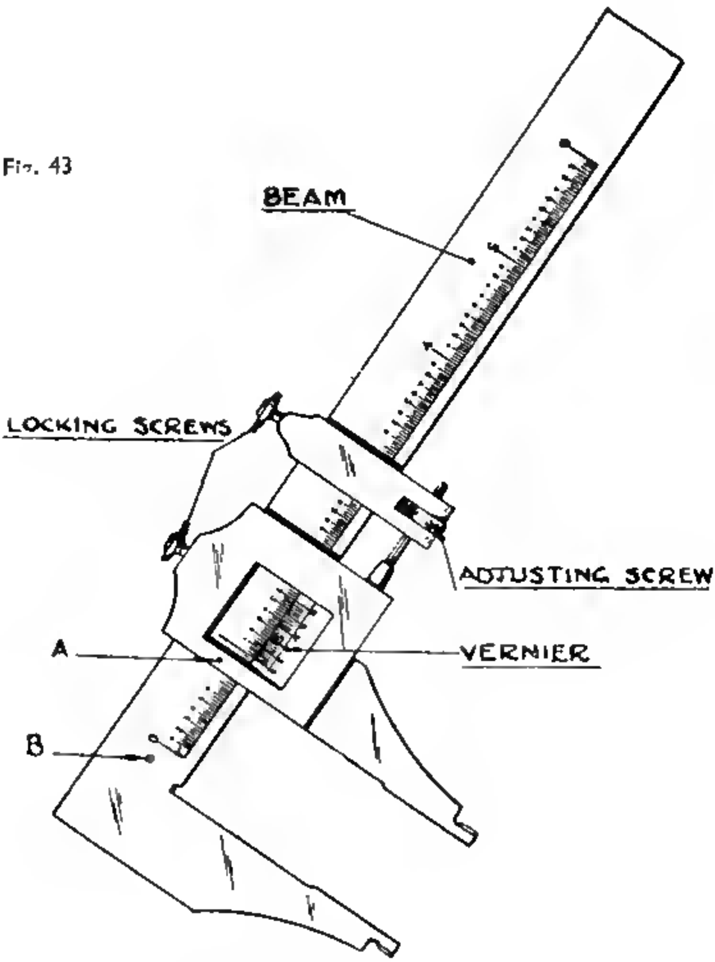
The *beam and vernier scale* are clearly shown in Fig. 45 and must be borne in mind during this explanation.

The beam is divided into inches, into tenths and into fortieths of an inch.

The vernier scale is .6 in. long and is divided into twenty-five equal parts.

On the beam .6 in. is divided into twenty-four equal parts which will be obvious.

Fig. 43



VERNIER CALLIPER.

Now the distance between each of the twenty-four divisions on the beam = 1/40 =.025 in.

The distance between each of the divisions on the vernier scale = .6 in. divided by 25 = .024 in.

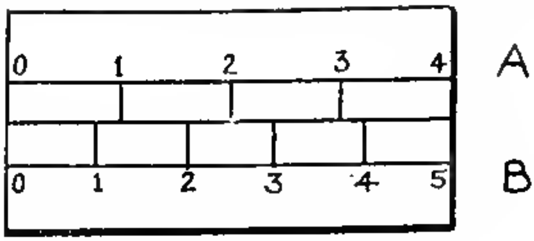


Fig. 44

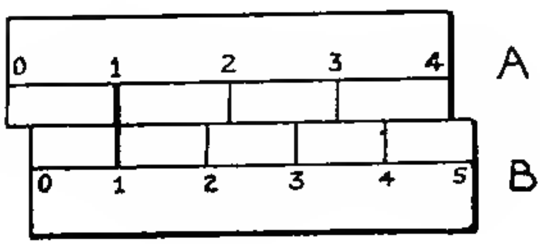


Fig. 44a

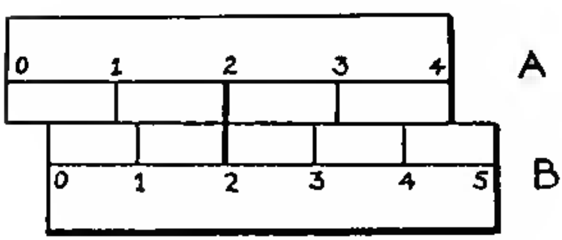


Fig. 44b

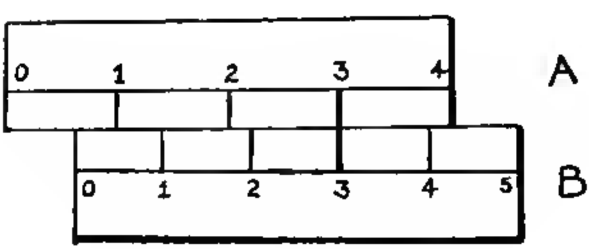


Fig. 44c

The. difference then = .025 in. minus .024 in. = .001 in. or one-thousandth of an inch. So if we move the jaw to which the vernier scale is attached until the first line on the vernier from zero is opposite the first line on the beam a distance of one-thousandth of an inch will have been moved, and there will be a gap of one-thousandth of an inch between the jaws.

To take a reading :—

Count the number of whole inches passed to the left of zero.

Count the number of whole tenths.

Count the number of one-fortieths.

See where a line on the vernier is opposite a line on the beam and add this number of thousandths of an inch. See Fig. 46.

On the reverse side of a vernier, the scale is usually divided for convenience of measuring in millimetres, and fractions of a millimetre.

This reading will now be explained :—

The beam is divided into centimetres, millimetres and half millimetres.

The vernier is twenty-four half millimetres long, and is divided into 25.

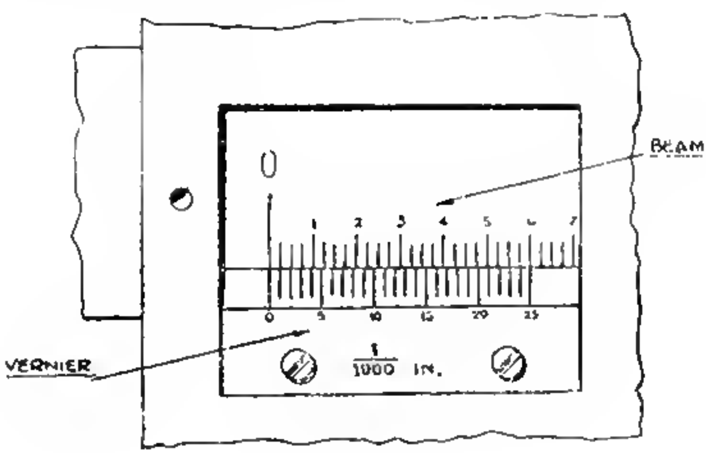
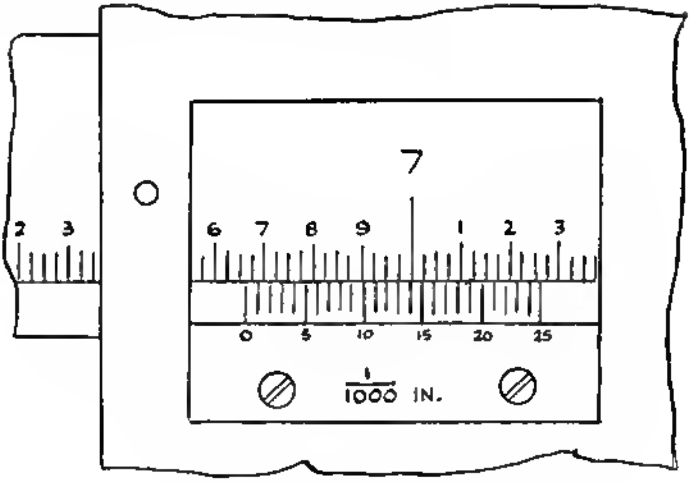


Fig. 45



VERNIER SET AT 6·662

Fig. 46

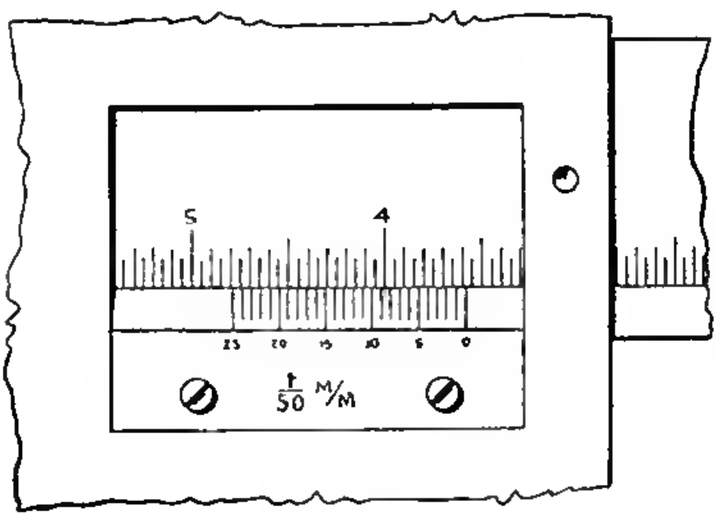


Fig. 47

The width of one division on the beam = one-half millimetre, or .5 mm.

The width of one division on the vernier = 12 millimetres or 24 one-half millimetres divided by 25 = 12/25 = .48 mm.

The difference then between one mark on the vernier scale and one division on the beam = .5 mm. minus .48 = .02 mm.

So if the first mark from zero on the vernier is brought to coincide with the first mark on the beam, a distance of .02 mm. has been passed.

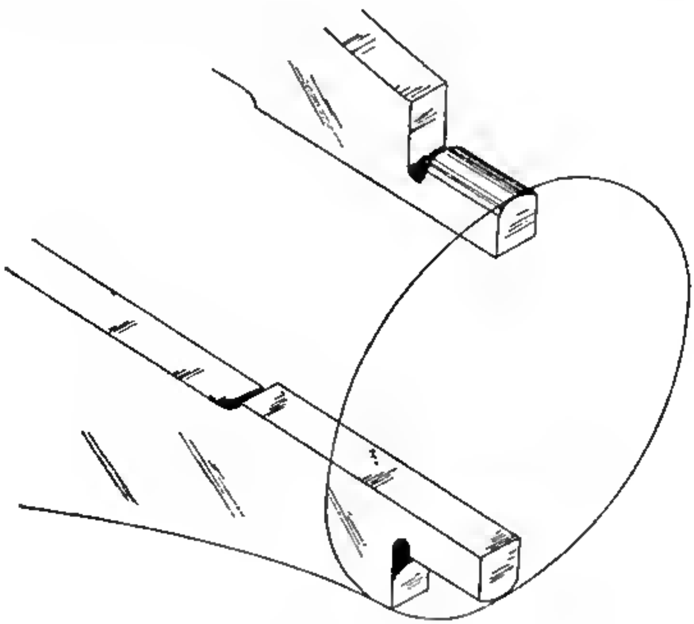


Fig. 48

An example of the reading is shown in Fig. 47.

How to take a reading :—

Count the number of centimetres and millimetres passed to the right of zero.

Add half millimetre if this has been passed.

See where a line on the vernier coincides with a line on the beam, each division = .02 mm., therefore, if the line coincides on 19 as in the example, 19 × .02 = .38 mm.

Now follow these rules in the example.:—

The number of centimetres passed by the zero on the vernier = 3.

The number of millimetres = 5, total 35 mm. One-half millimetre must be added, = 35.5 mm., and the line coincides on 19, that is: 19 × .02 = .38, so the total reading = 35.88 mm.

If you examine the vernier calliper, you will see two small holes as shown at "A" and "B" Fig. 43. The vernier is opened to the distance required and then the divider may be set to this distance by carefully placing the points in the small holes shown. The result will be far more accurate than can be attained by using a rule.

The jaws of a vernier, it will be noticed, are rounded at the end. This is for the purpose of measuring inside rings or holes. (Fig. 48).

It must be borne in mind that the thickness of these rounded jaws must be added to the vernier reading to give the correct size of the hole being measured. On a 12-in. vernier the jaws usually measure .3 in.

So, if for example, on taking the measurement of the diameter of a hole the micrometer reading was found to be, say, 2.235 in., then the true diameter of the hole would be :— 2.235 in. plus the thickness of the jaws .3 in. = 2.535 in. The vernier, of course, only gives a reading which indicates the distance inside the jaws, that is why the thickness of the two half-round jaws must be added.

Considerable skill is required before this instrument can be successfully used by the artisan, but practice makes perfect.

It is often a surprise and a source of annoyance to young men who, after spending several years in the workshop, find themselves capable of doing the work of established workmen, but having to be content with considerably less pay. The fact they usually forget is that while a boy is learning he is costing his employer money, and artisans at first seldom improve tools by learning how to use them.

The micrometer and vernier are both expensive instruments, and the artisan must use them with the greatest care and respect.

It does not require much effort for a strong young man to *force* the jaws of the vernier calliper over a piece of steel *greater* in size than the size at which the vernier is set, or to *squeeze* the outside jaws into a hole *smaller* than the vernier size. What happens is exaggerated in Figs. 49 and 50.

The false application of force as shown is sufficient to ruin the vernier calliper.

Of course, it is assumed that the boy who reads this book has more common sense than to behave in this manner, but such misuse of a vernier calliper has been done before now, and will surely be done again by somebody. Obviously all measurements taken by a vernier calliper whose jaws have been bent in or out will be incorrect.

Before using a vernier calliper, clean the jaws, close them together, making sure the locking screw is half tight, and holding the jaws against the light see if any light is passing between them. This precaution may not only prevent you

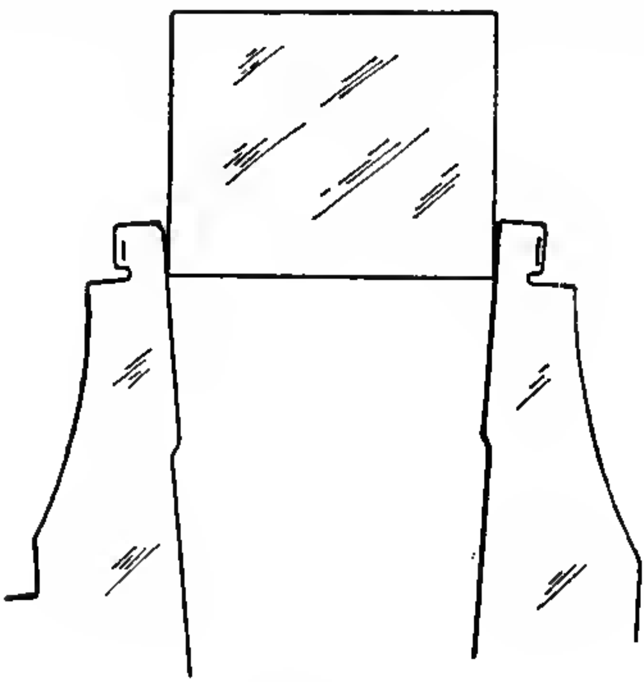


Fig. 49

being blamed for the abuse of the instrument, but will certainly prevent errors in your work.

The principle of the vernier is applied to the vernier height gauge (Fig. 34, page 34).

So we have an instrument which we may use for marking out to one-thousandth of an inch.

When the height gauge is new, the distance from the base to the first marking is usually exactly one inch, but, with use, the base of the gauge becomes worn and the distance therefore untrue.

It is better to begin marking out work from the top of a pair of parallel strips (*see* Fig. 28, page 29), first measuring the height of the strips and calculating all distances from the figure so obtained.

To measure the height of an object by height gauge is a matter of skill and touch. The operation, however, will be considerably simplified if a little marking compound is applied from the finger to the underside of the bit, the bit lowered close to the surface to be measured, and the final

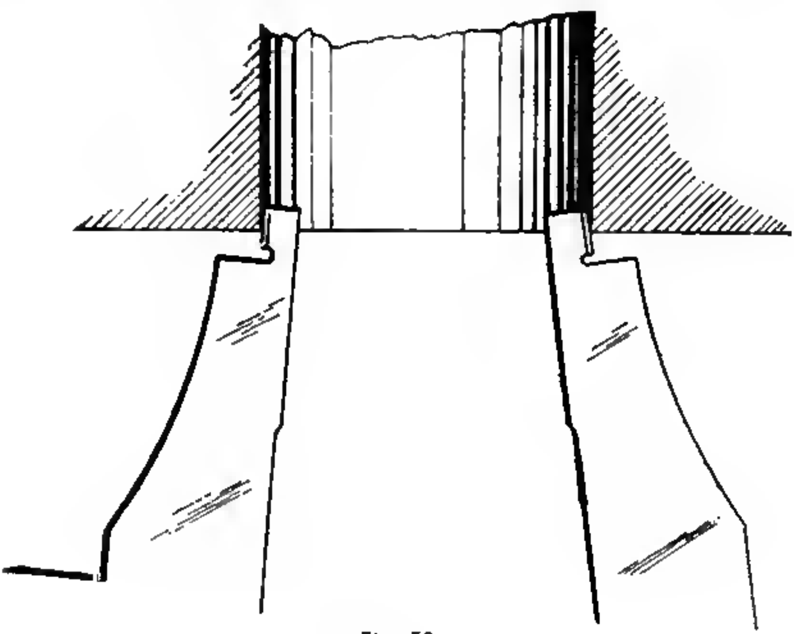


Fig. 50

adjustment made as usual by the adjusting screw until, when the bit is moved over the surface, the marking compound shows. (Fig. 51.)

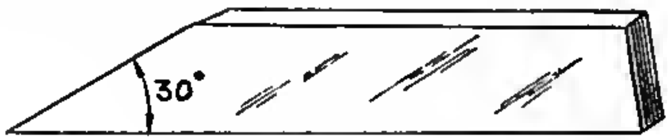


Fig. 51

The bit of the height gauge must be ground on a surface grinder.

It is imperative that the bit underside be perfectly flat.

It may, however, be sharpened by hand on a good flat oil stone, if not too badly worn.

The height gauge is very liable to damage by being dropped even once.

The vertical height it occupies on the surface plate, together with its lightness, makes it susceptible to accidental blows. It must be carefully used.

The vernier principle is applied to the vernier protractor.

On each side of the zero line on the vernier scale there are twelve divisions representing sixty minutes (60′). To whichever side of the zero line on the main scale the vernier is moved, that is the side to use.

From No. 0 to No. 60 on the vernier represents a length of 23 degrees (23°) on the main scale. There are twelve divisions between 0 and 60. Each division is, therefore, 23/12 deg. = 1 11/12 deg. = 115 mins.

Now 2 deg. = 120 mins., therefore each division on the vernier is 5 min. less than 2 deg. on the scale.

The difference then between the first mark on the vernier and the two degree marks on the main scale = 5 mins.

The difference between the second mark on the vernier and the fourth mark on the scale = 10 min. and so on.

To take a reading :—

First see the number of whole degrees between the zero on the main scale and the zero on the vernier scale.

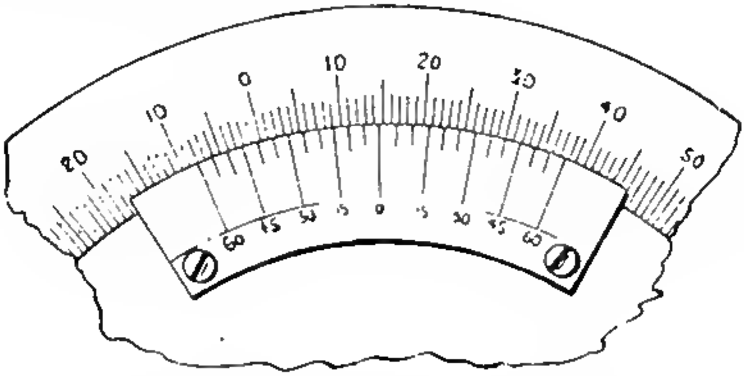


Fig. 52

Next see which line is the nearest to coinciding, and that will be the numher of minutes to add.

In the example the reading is: 14 deg. 40 min. (Fig. 52.)

The vernier as applied to the micrometer for the purpose of reading to one ten-thousandth of an inch is effected in the following way :—

There are ten divisions on the barrel occupying the same distance as nine divisions on the thimble, the difference then between one division on the harrel and one division on the thimble will equal one-tenth of one thousandth = one ten-thousandth part of an inch.

To find out the smallest part of an inch which can be read from any vernier, you need only find out what part of an inch is the smallest division on the main scale, and divide it by the number of divisions on the vernier scale.

CHAPTER XI

SCREW THREADS

MOST people are familiar with the two objects, a bolt and a nut.

Bolts, nuts and set screws are such common objects that they may be seen in modern times even in places distinctly removed from towns and cities. The engineer uses screws for a great variety of purposes, not only to hold parts together, but to transmit motion and to measure by as, for instance, a micrometer.

The commonest form of screw thread is the "British Standard Whitworth," but you will probably not find a single B.S.W. thread on, say, a bicycle. Bicycle threads are of a special fine structure, but, again, you will probably not find a single thread of this form, say, on a sewing machine. From which it may be deduced that there are many kinds of threads to suit different purposes, and satisfy special requirements.

The shapes of these threads and their angles are laid down in very specific rules.

It is not very important at this stage that the beginner has the various thread forms, angles and proportions at his fingertips. What is important is that he can recognise a type of thread when he sees it, and that he can judge for himself what type of thread to use for a particular purpose. Fig. 53 shows a British Standard Whitworth bolt (called B.S.W., for short) and, drawn much larger so as to be clearly seen, there is also shown a small portion of the thread giving details of its shape.

It is the most common thread to be seen in workshops, excluding instrument workshops.

On every ship that puts to sea, there are thousands of

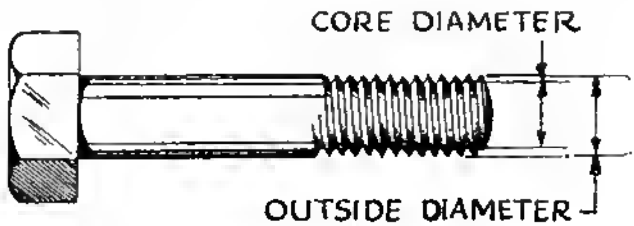
Whitworth bolts and nuts from $\frac{3}{16}$ in. diameter to 2 in. and larger.

Every engine that travels the rails is held together by countless Whitworth bolts.

Since the thread is standardised, a half-inch Whitworth bolt will fit a half-inch Whitworth nut, although the two may be bought and manufactured even in different countries.

Another very common thread is the "British Standard Fine" (called B.S.F., for short).

B.S.F. threads are of exactly the same form as B.S.W. threads, the only difference being the *pitch* or the number of threads to the inch. This difference enables smaller adjustments to be made, and the bolt has less tendency to work loose through vibration.



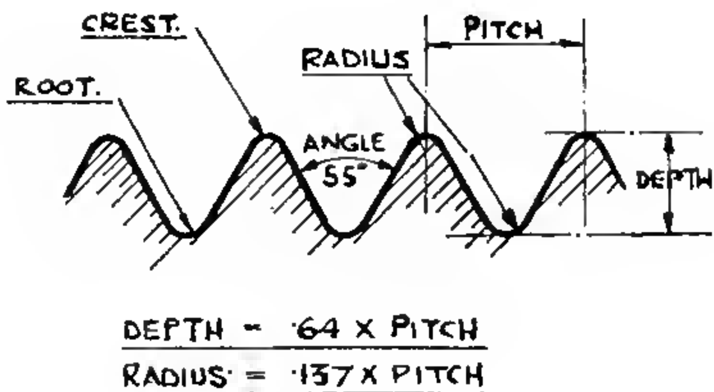


Fig. 53

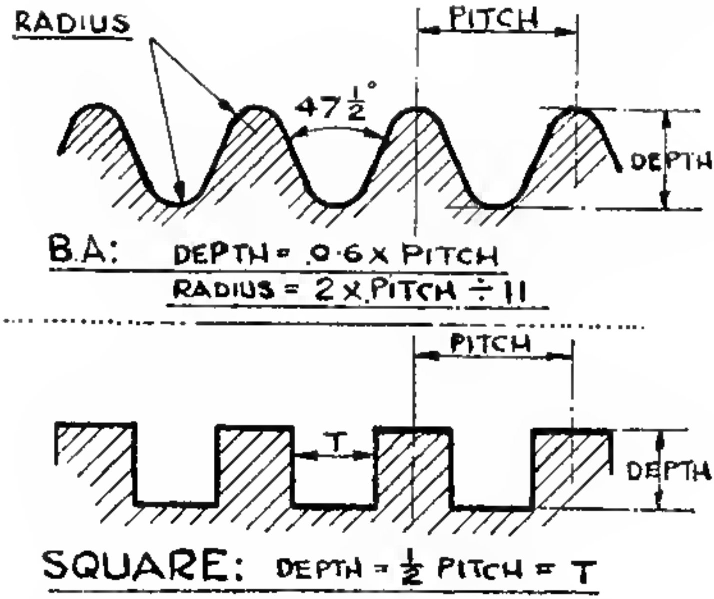


Fig. 54

The core diameter is consequently greater on a B.S.F. bolt than on a B.S.W. bolt, as the depth of thread is proportional to the pitch, a point to be borne in mind when drilling a hole to tap B.S.F. This will be better understood after reading the chapter on "tapping."

Whitworth threads smaller than $\frac{3}{16}$ in. diameter and B.S.F. threads smaller than $\frac{1}{4}$ in. diameter are seldom used. For screws and bolts below these sizes, "British Association" threads, called B.A., are used. A section of this thread is shown (Fig. 54).

It is normally used on small instrument work. The sizes are designated by numbers, 0 to 25, but the sizes employed as a rule are Nos. 0, 2, 4, 6, 8 and 10.

The larger the number, the smaller the diameter of the thread.

It has been noted that the engineer uses threads for transmitting motion.

If you will examine the lead screw on a lathe machine, you will find it is either a *square thread* or an *acme thread.*

The difference in the shape of these threads may be easily seen from Figs. 54 and 55.

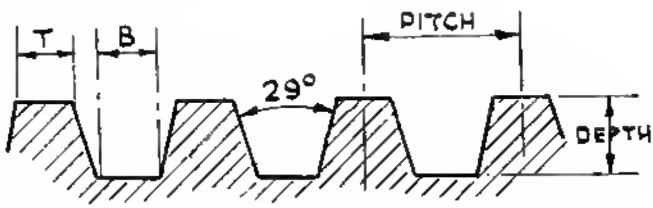
In practice the square thread has a tendency to " grow " and bind in the nut.

The " acme thread " is far superior and is easier to cut.

Another thread for transmitting motion is the " buttress thread." It is used principally on bench vices where the thrust is constantly one way only.

The " Sellars thread " or " American thread " serves the same wide general purpose in America as the *Whitworth thread* serves in Britain.

A sketch of its proportions is given alongside the " buttress thread " (Fig. 56).



ACME.- DEPTH = 1/2 PITCH + 0·010"

B = 0·37 × PITCH − 0·005"

T = 0·37 × PITCH

Fig. 55

Another thread which may be mentioned is the " British Standard Pipe " thread or B.S.P., but here again, as in the B.S.F., there are more threads to the inch, although the form is Whitworth.

It is usually confusing, when this thread is specified to be used, to find that the size given does not correspond with the actual size which the finished thread presents. For instance, if you ask in a workshop for a $\frac{3}{8}$-in. B.S.P. die to cut a thread, the outside diameter is not $\frac{3}{8}$ in. as on other threads but considerably larger. The reason is that the pipe thread is usually cut on a pipe, and the size given is the *inside diameter* of the pipe.. The " outside diameter " of a thread for a pipe of 2-in. bore is not, of course, 2 in., but 2.35 in., the thickness

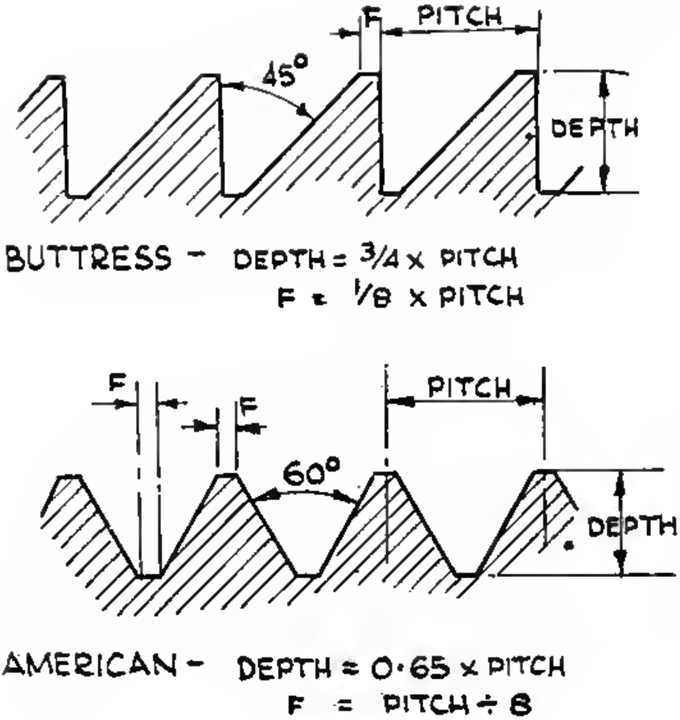

F
PITCH
45°
DEPTH
BUTTRESS - DEPTH = 3/4 x PITCH
F = 1/8 x PITCH
F
F
PITCH
60°
DEPTH
AMERICAN - DEPTH = 0·65 x PITCH
F = PITCH ÷ 8

Fig. 56

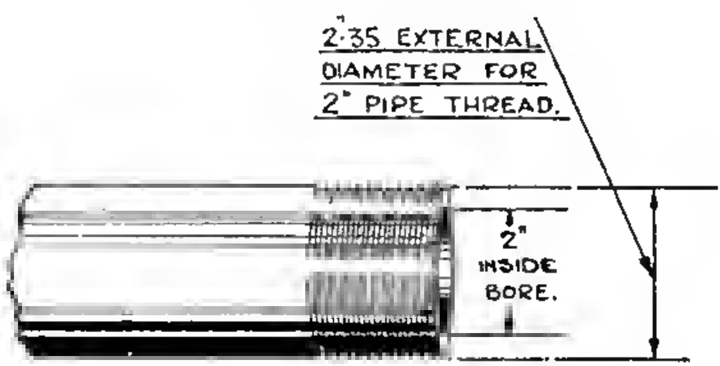

2·35 EXTERNAL
DIAMETER FOR
2" PIPE THREAD.
2"
INSIDE
BORE.

Fig. 57

of the pipe wall being of a standard measurement, which makes this so. (Fig. 57.)

It is as well to understand the different terms relating to threads.

The *angle, outside diameter, core diameter, root* and *crest* are clearly indicated in Fig. 53.

" Pitch " also is shown and can be described as the distance from a point on one thread to a corresponding point on the next thread.

Notice in the sketches of thread sections, the proportions of " actual thread depth " given in terms of pitch. This knowledge is not only useful to the man on the lathe who has to cut threads, but is a useful guide in selecting a drill suitable for " tapping," as will be explained later.

CHAPTER XII

BOLTS, NUTS, SCREWS AND LOCKING DEVICES

If you were asked to bring a cheese-head $\frac{1}{4}$ in. diameter Whitworth screw 2 in. long, could you confidently select the right screw from a number of others? If you could, you will still probably find something in this chapter you did not know before; if you could not, then you must learn to do it at once.

Bolts and nuts are made in many forms for various uses, but the four principal forms are hexagon, square, round-head and tee-bolt (Fig. 58).

Nuts are nearly always square or hexagon.

"Set screws" differ from bolts in one way principally, and that is, the thread on a bolt finishes some distance from the bolt head, but the thread on a set screw is continued right up to the head.

Set screw heads are made in the shapes shown in Fig. 59.

The threads on bolts and set screws are principally Whitworth, B.S.F., and B.A., so if a bolt or set screw is required, the length, the type of thread and the shape of the head must be specified.

Bolts differ from set screws in another way; whereas set screws are always "bright," that is, machine-finished all over, bolts may be either "bright" or "black."

Black bolts are finished to shape by forming the metal to the correct shape while it is hot, and then the thread is cut by a die and the bolt is finished. Bright bolts, on the other hand, are machined from bright rolled hexagon steel bar and are true to standard size specifications.

"Allen screws" (Fig. 60) are special types of screws used where it is required that the screw head be below the surface of the work.

The cheese-head and countersunk-head screws are used for this purpose, but as the only means of tightening them is by means of a screwdriver fitting into the slot, they cannot be made tight enough to satisfy every requirement.

The "Allen screw" has a hexagon-shaped recess sunk into the head, into which is placed the "Allen key," (Fig. 60) which is a hexagon-shaped piece of strong steel bent at 90 deg. By this means, the screw can be made very tight. "Allen screws" are supplied in the usual thread forms, Whitworth, B.S.F., and B.A. They differ in another way from ordinary screws in the fact that they are manufactured from tougher steel.

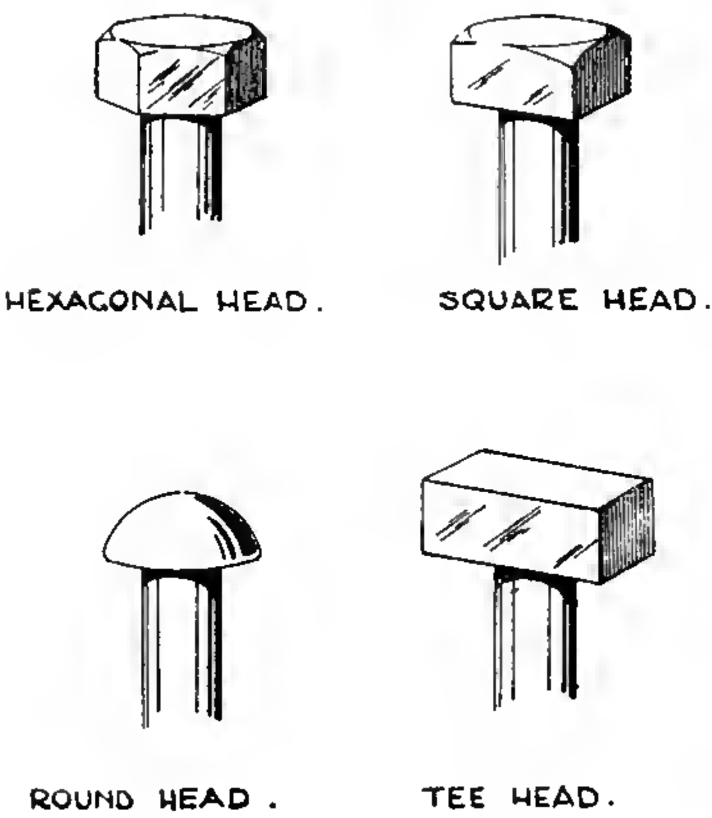


Fig. 58

All bolts and screws should be given a drop of oil before being fitted finally into the work to facilitate easy release. This is especially true of Allen screws which sometimes " bind " so tightly into the thread of the hole that when it is attempted to take them out they break off, or else bend the Allen key. The fitter is then presented with a very unpleasant situation.

A note on tightening square and hexagon-headed nuts :—

See that a spanner of the correct size is used.

If the spanner is too big, it will spoil the shape of the nut by rounding the corners, and, what is more important to the workman, the spanner may slip off the nut completely and he will probably injure himself.

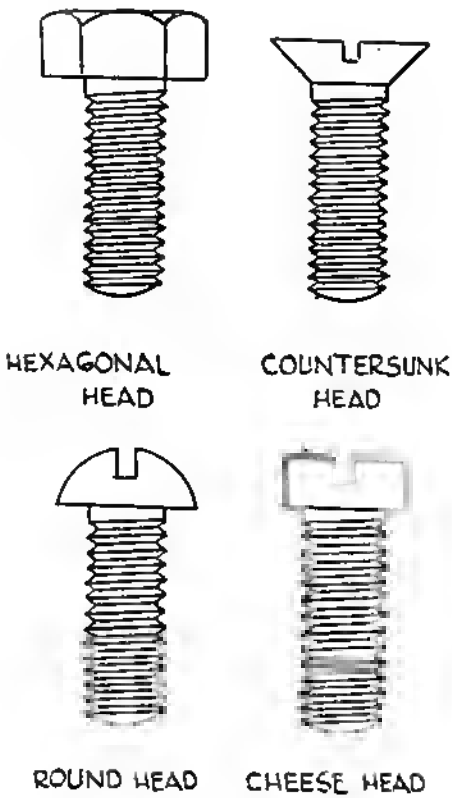


Fig. 59

However tightly a nut and bolt are secured, they will become loose under the effects of constant vibration unless some precautionary measure is taken to guard against this.

The commonest form of locking device is a nut of smaller thickness tightened below the actual nut. Two spanners are used, and when the locking nut has been tightened, the ordinary nut is tightened on top of it while still holding the locking nut in its original position by means of another spanner (Fig. 61).

Another system of locking is by use of a castle nut. The castle nut is first screwed down tight on to the work, and then a hole is drilled through the bolt in line with any two slots. Into this hole a split pin is inserted and opened out.

Before inserting the split pin, open it slightly with a chisel or screwdriver, then, closing it by the pressure of the fingers only, push it through the hole. It will then be found to be an easy matter to open it by means of a chisel.

When the nut and bolt are likely to be a permanent fixture, they can be locked either by riveting the bolt over the top of the nut, or by destroying by means of a blunt chisel, the thread immediately above the nut. "Spring washers"

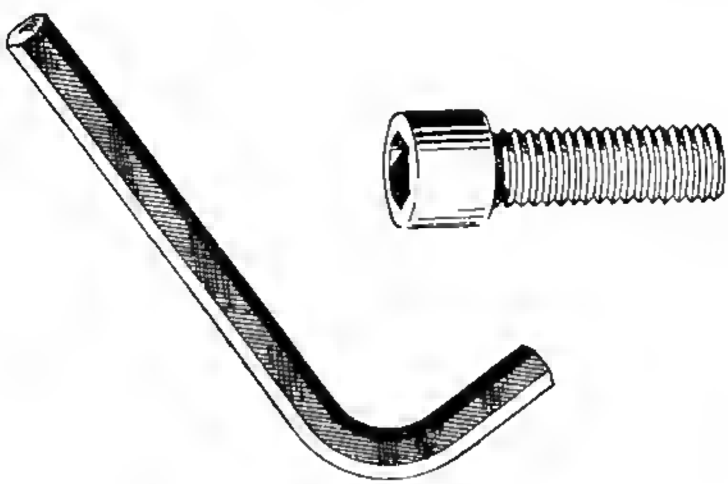


Fig. 60

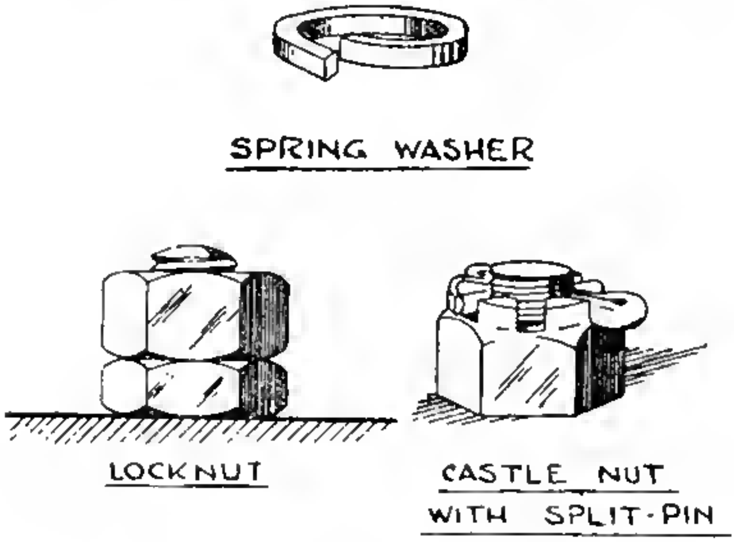


Fig. 61

placed underneath the nut previous to tightening are another very satisfactory method of locking.

Many patent designs for locking nuts are in use in the aircraft industry, but they need not be mentioned specially here.

A bolt is not safely secured unless the nut is holding as much thread as its depth allows. Serious accidents occur when nuts are only holding by a few threads, or when they are unfairly tightened by the use of tubes on the spanner.

It is quite easy completely to strip the thread from a bolt by both these abuses.

CHAPTER XIII

DRILLS, REAMERS AND CUTTERS

Twist drills are used for the purpose of drilling holes in metal, and are a comparatively modern invention. Previously the spear drill was used. The spear drill is merely a piece of suitable steel, beaten out to shape by the blacksmith, hardened, tempered and ground to the correct shape.

The size of such a drill cannot be guaranteed, the speed of cutting is slow, and the drill has to be constantly re-beaten out and shaped again.

The modern twist drill is as near perfection as it is possible to get.

Study Fig. 62 and memorise the different angles and names of parts of a drill.

The point of the drill is actually pushed through the metal, while the lips of the drill cut off the chips of metal, which are carried away into the flutes.

The cutting angle has been found to give best all-round results when it is 118 deg., although variations of a few degrees greater or smaller will not give noticeably poorer results.

Drills ground on special machines give better results than drills ground by hand, although every fitter should have the ability to grind a drill successfully by hand, and to do this really well requires only perseverance, observation and practice.

Three angles have to be taken into consideration, the *cutting angle*, the *point angle* and the *clearance angle*.

For all round service the *cutting angle* should be 118 deg., inclusive.

The *point angle* should be approximately 130 deg. and the

clearance angle may vary from 5 deg. to 12 deg., depending on what kind of metal the drill has to be used.

For soft metals, such as aluminium or brass, the *clearance angle* should be greater than when drilling mild steel, and when hard steel, such as cast steel is to be drilled, the *cutting angle* should be at the minimum of 5 deg.

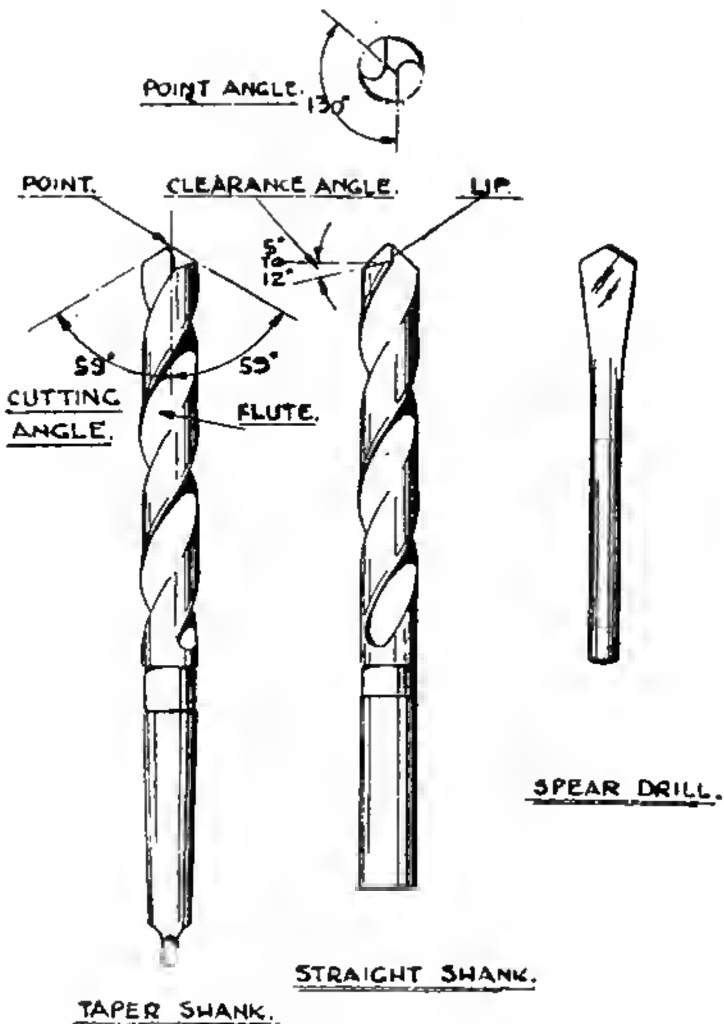


Fig. 62

The important thing is, that the lip of the drill should be higher than the back or the drill will not cut.

The *point* too must be in the centre, or the hole will be much larger than the diameter of the drill.

The lips should be of approximately the same length.

It is surprising how quickly the eye becomes trained to recognise any deficiency in the shape of a drill, providing a little thought and care is taken, and providing the mind's eye is carrying a picture of what a correctly ground drill looks like.

If the cutting angle is considerably more than 118 deg., the drill will have a flat appearance.

The increased strain of the shortened lips will cause them to crack and small chips will break off.

A drill must be re-ground at the first sign of chipping.

If the cutting angle is too small the drill will appear excessively pointed, the lengthened lips will become hot through too great a contact with the metal and the drill will burn and become blue at the end. Again, a drill must be re-ground at the first sign of burning, and *all* the burnt edges ground out.

The most serious fault made by beginners is running the drilling machine either too fast or too slow to suit the size of drill being used.

Another fault is the application of too much or too little pressure on the machine handle. Too little pressure will cause the drill to become hot and burn, while too much pressure will cause the drill to become fast in the work and break.

The speed at which the drill revolves is called the *speed*.

The depth the drill sinks into the metal in a certain time is called the *feed*.

Experiment has determined the best speeds and feeds at which to use drills of any diameter, but to the practical man working in a workshop his experience serves as his guide.

Few fitters when using a drill calculate the motor speed, the ratios of the pulleys on the shaft and the machine before commencing to drill a hole, and few artisans will find themselves in a workshop where there are no skilled men to ask or imitate.

Drilling is not hard work if the drill is correctly ground, a suitable speed and feed employed and some *coolant* regularly applied.

Care must be taken when the drill is breaking through the metal; the pressure on the handle must be decreased and the drill fed through easily.

Aluminium may be drilled considerably faster than, say, mild steel, and the best coolant for this metal is *paraffin*.

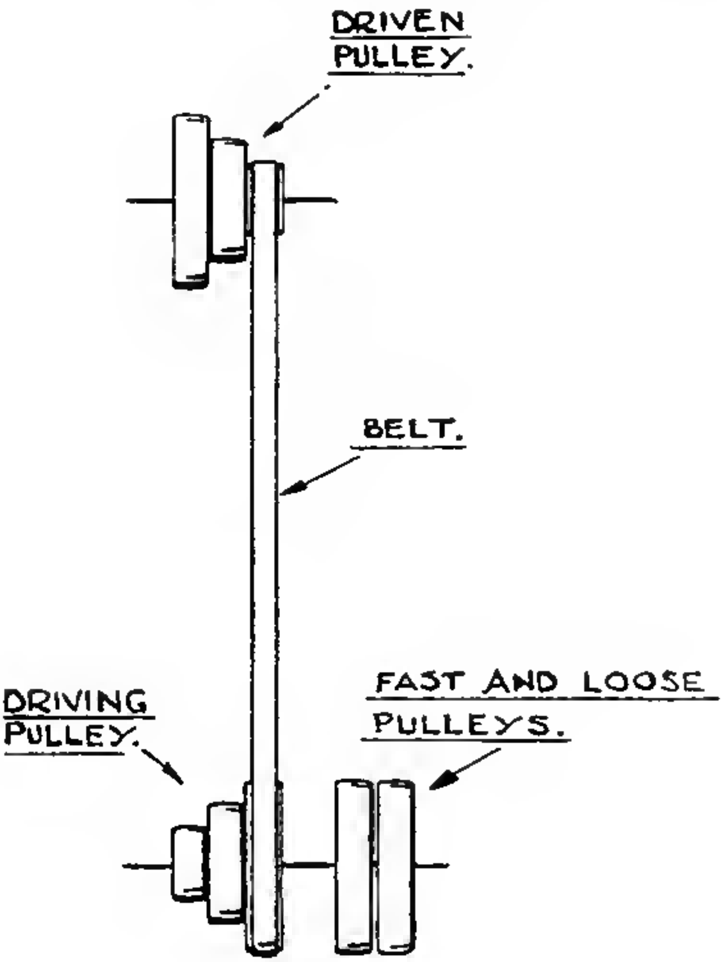


Fig. 63

Strangely enough, however, aluminium wears away a drill quicker than steel, and the drill must be kept quite sharp.

Brass is a dangerous metal to drill, as it has a tendency to climb up the drill as the hole is breaking through. A *stop* should be bolted on the machine above the work to prevent this. (Fig. 64.)

Soluble oil is a suitable coolant.

Mild steel drills easily and soluble oil or machine oil is a suitable coolant.

The fitter has occasionally to drill hard steels, such as cast steel, die steel, nickel steel, etc. The speed of the drill must be comparatively slow, the drill must be ground to the minimum clearance angle and turpentine used as a coolant.

When a hole bigger than $\frac{5}{8}$ in. diameter is to be drilled, the work will be made considerably easier if a small " pilot " hole is drilled first to clear the drill point.

Another advantage of the pilot hole is that, as the drill is not gyrating with the point as a radius centre, the hole will be true to size.

The pilot hole, however, must not be much bigger in diameter than the point of the drill is in width, or the lips will be damaged.

Frequently it is required to countersink a hole to take a *cheese-head set screw* or an *Allen screw*.

The large drill should be used first to the required depth and the smaller drill afterwards, in this way you may be sure that both holes are in line. When using a straight shank drill in a chuck, tighten the chuck firmly by means of the key provided or the drill will turn in the chuck and damage the shank.

Drills are also often used to make *countersinks* for *countersunk screws*.

The fitter will find, especially if he is countersinking into a hole, that the drill " chatters," that is, instead of having a smooth " V "-shaped recess, he has a countersink which is jagged and composed of a number of flats. A piece of oily rag placed underneath the drill will help to eliminate this fault.

There is danger in using a drilling machine, as there is

in all machine work, so a word of caution and advice :—

Always use a stop to prevent the work from becoming fast on the drill and spinning round.

When the job may be fixed in a machine vice, secure it in this way, and if the hole is larger than ½ in. diameter bolt the vice securely to the table.

Make sure both the locking handles on the machine table and behind the pillar are fast, before drilling.

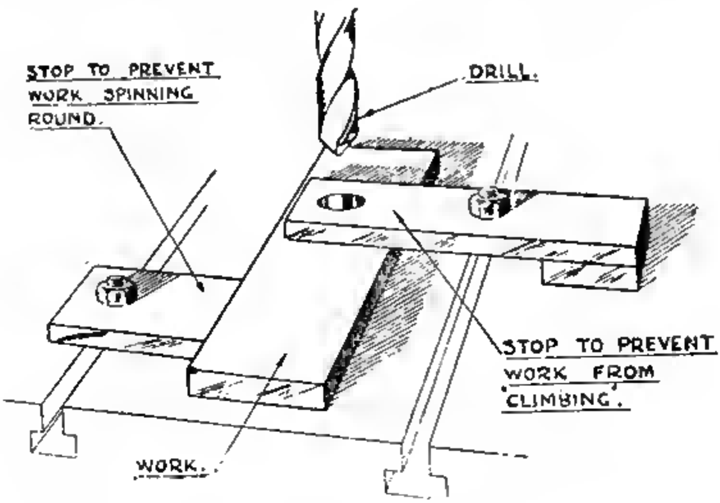


Fig. 64

Apply coolant with a brush or an improvised spoon and *not by hand.*

Use a brush to remove the *swarf,* that is, the pieces of steel cut off by the drill. " Swarf " is *razor sharp* and will cause a bad cut on the fingers.

Take special care when drilling thin metal. Fasten it to a piece of scrap steel and drill into the scrap steel also.

The beginner will probably not notice at once that the speed of the machine is governed by a belt connecting two pulleys, each having wheels of three different sizes.

The belt may be fixed on any two wheels. In the sketch the belt is on the largest wheel of the driving pulley and on the smallest wheel of the driven pulley, so when the driving pulley turns round *once* the driven pulley, being smaller,

will turn round more than once. This is the fastest speed at which the machine will run.

When the belt is on the two pulleys which are of the same diameter the speed will be slower, and the slowest speed is obtained when the *smallest* wheel on the driving pulley is connected to the largest wheel on the driven pulley.

If it is required to drill a hole of, say, $\frac{1}{4}$ in. diameter, then the fastest speed must be used, while if a hole of 1 in. diameter is to be drilled, the slowest speed will be employed.

Speeds on modern machines are changed by means of levers and gears, which are enclosed.

Types of machines and speeds of motors vary so considerably in workshops that it is quite impossible to give in a book any instruction excepting of a general nature. The best general guide is the behaviour of the drill.

When drilling is hard work, see if the drill is sharp, and make sure your speed is not at fault and that you are using some coolant to prevent the drill becoming hot.

Resist the temptation to seize swarf in the finger as it leaves the drill, or you will surely regret it.

If you want to *change speed*, stop the machine first, change the belt and start again.

Make sure the device to stop the machine is within easy reach.

Keep swarf and rag away from the revolving drill.

Loose clothes such as *neckties, loose sleeves.* and *shirts* are especially *dangerous.*

It is advisable when drilling holes larger than $\frac{3}{4}$ in. diameter to fix a *stop to hold the work down,* as well as *to prevent it* from *swinging round.*

Reamers are used after drills to ensure that the hole is smooth and true to size.

Machine reamers (Fig. 65) are taper shank, hand reamers straight shank.

There is more strength behind the cutting edge of machine reamers as they are subject to more severe wear than hand reamers.

Hand reamers, however, may be used in the same way as straight shank drills, providing the speed is very slow.

MACHINE REAMER. TAPER SHANK

HAND REAMER. STRAIGHT SHANK.

Fig. 65

Some skill is required to enter a hand reamer into a hole and by means of turning with a tap wrench (*see* page 87) ream the hole smooth and true, whereas, if the reamer is held in a drill chuck and used with a slow feed and speed, the hole will be both smooth, straight and true to size.

Hand reamers are tapered to a greater degree than machine reamers to make it easy to start the reamer in the hole.

How much metal must be left in a hole when a reamer is to be used after the drill?

The less metal you can leave to be removed by the reamer the better will be the result. This is a general rule.

The amount of metal to be left in the hole will be proportionate to the size of the hole.

Drills are supplied in number sizes, in letter sizes, in fractional sizes and in metric sizes.

The drills at the disposal of a fitter are, generally, *number drills*, *letter drills* and *fractional drills*.

Number drills from No. 1 to No. 80 are small—sizes ranging from No. 1 = .228 in. diameter up to No. 80 = .0135 in. diameter.

Letter drills range from letter A = .234 in. up to letter =.413 in.

Fractional size drills range from 1/64 in. up to, say, 3 in., rising by 1/64 in.

As it is unusual to ream a hole greater than 1 in. in diameter, we will consider this the largest hole to be reamed for the

purpose of demonstrating the relationship between drill and reamer.

Number drills are used before reamers up to $\frac{1}{4}$ in. diameter.

To take an example :—

Suppose it is required to drill and ream a hole of $\frac{3}{16}$ in. diameter, the most suitable drill would be a No. 14 drill = .182 in. Now, $\frac{3}{16}$ in. is .187 in., so .005 in. is left to be removed by the reamer. Consider again a $\frac{1}{8}$-in. drilled and reamed hole. The most suitable drill will be a No. 31 drill = .120 in., $\frac{1}{8}$ in. = .125 in., so again .005 in. is left to be removed by the reamer.

The practice of leaving .005 in. in the hole, although perfectly suitable for small holes, is quite unsatisfactory in larger holes, where the drill may easily make a hole .010 in. greater than the true diameter of the drill.

A suitable reaming drill for a $\frac{5}{16}$ in. reamer would be a letter N drill, for a $\frac{3}{4}$-in. reamer 47/64 in., and for a 1-in. reamer 31/32 in.

A table giving sizes of drills for reamers of nominal sizes has been compiled below and should be *memorised* :—

Reamer size	*Drill size*
$\frac{1}{8}$ in.	No. 31
$\frac{3}{16}$ in.	No. 14
$\frac{1}{4}$ in.	Letter D
$\frac{5}{16}$ in.	Letter N
$\frac{3}{8}$ in.	Letter U
$\frac{7}{16}$ in.	27/64 in.
$\frac{1}{2}$ in.	31/64 in.
$\frac{9}{16}$ in.	35/64 in.
$\frac{5}{8}$ in.	39/64 in.
$\frac{11}{16}$ in.	43/64 in.
$\frac{3}{4}$ in.	47/64 in.
$\frac{13}{16}$ in.	25/32 in.
$\frac{7}{8}$ in.	27/32 in.
$\frac{15}{16}$ in.	29/32 in.
1 in.	31/32 in.

The above tables will be found satisfactory, provided the drill point is ground properly to the centre of the drill, and for sizes larger than $\frac{5}{8}$ in. a pilot hole is first drilled.

If a hole is to be reamed to fit tightly a steel pin already made, measure a few reamers of the size required by a micrometer and select the one that is slightly smaller than the pin.

Remember, if the reamer has an uneven number of flutes such as five or seven, you cannot measure its diameter by using a micrometer.

When taper pins have to be fitted into work, taper reamers are used to shape the hole to the correct taper.

Taper pins are given numbers from No. 00000 up to No. 14.

When you know the number of taper pin to be fitted, ream the hole with the same number taper-pin reamer.

First drill a hole approximately the same size as the smallest end of the taper pin or slightly bigger.

The work of reaming is reduced if the taper is helped by means of a few drills, increasing in size suitably and drilled at different depths.

Three cutters which help the fitter in his work may now be described.

The Fly Cutter

This is used to cut holes in sheet metal. As will be seen from Fig. 66, it consists of a cylindrical piece of steel turned small on top to a size suitable for entering a drill chuck, while the other end has a small pin of any nominal size, such as $\frac{1}{4}$ in.

A square bar slides through a square hole in the body and may be adjusted to suit different diameters to be cut, and locked in place by a screw.

The guide pin is placed in a hole of the same size, previously drilled.

Aluminium and brass may be cut very rapidly and steel also may be cut very slowly, if the cutter is hard and ground correctly and some coolant applied.

An easily made counterbore for cutting a flat surface on which a bolt head is to rest, or making a hole to take the head of a screw, consists of a piece of steel about $\frac{1}{2}$ in. or $\frac{5}{8}$ in. diameter which has two holes drilled through it at right angles. These holes are drilled at such a distance apart that they cut into each other by 1/64 in.

The cutter has a flat portion filed in the centre, and this flat comes in contact with a flat filed on the wedge which is driven in on top, securing the cutter.

The cutter may be $\frac{1}{4}$ in. diameter cast steel for $\frac{1}{2}$ in. shank and $\frac{3}{16}$ in. diameter cast steel for $\frac{3}{8}$ in. shank.

The third cutter can quickly be made on a lathe from a piece of cast steel, filed to the centre line as shown, and hardened and ground.

It will be found very useful for removing burrs from drilled holes and for countersinking.

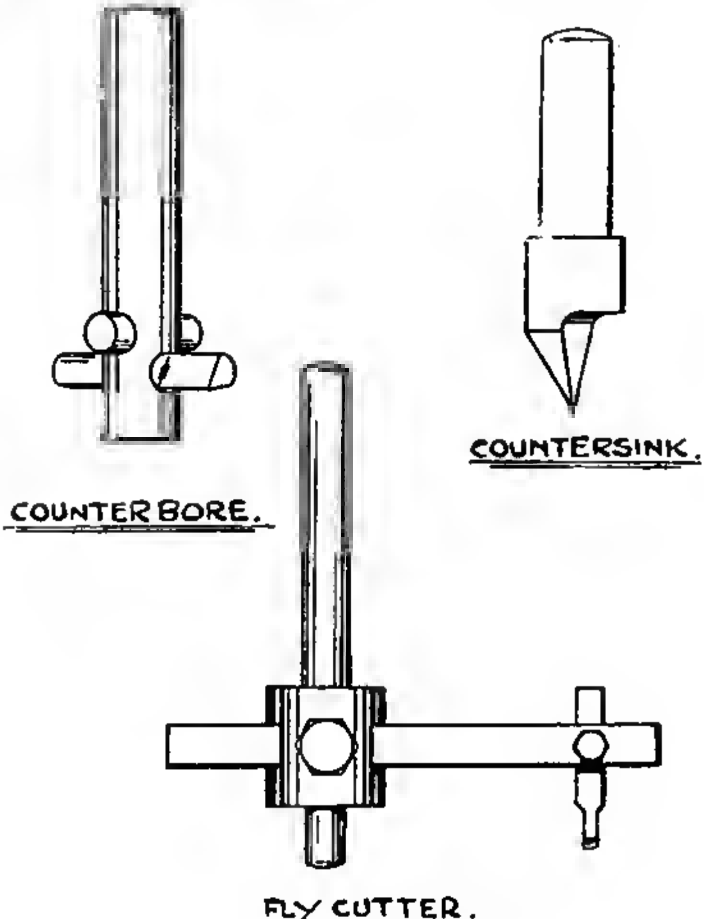


Fig. 66

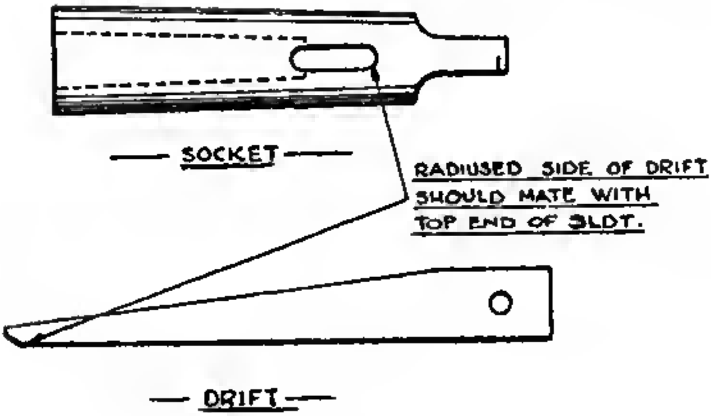


Fig. 67

It will be noticed that the taper shanks of large drills are greater in size than the shanks of small taper-shank drills. To make it possible to fit these small shanks into the large spindle of a drilling machine sleeves or sockets are used. (Fig. 67.) The smallest size taper-shank drill will fit No. 1 sleeve. This sleeve is then placed in a No. 2 sleeve and the No. 2 into a No. 3 which will fit the drilling machine. When the sockets are assembled, strike the assembly on a piece of wood to make sure the sleeves are firm, and having placed them in the drilling machine, press the drill on a piece of wood to secure the sockets in the drilling machine. Keep the sockets clean and free from burrs and use a proper drift to knock them out.

CHAPTER XIV

TAPS AND TAPPINGS

SCREW threads are cut inside holes by means of *taps*.

Taps are supplied in sets of three, called taper tap or first tap, second tap and third or plug tap.

The taper tap is so shaped that it will enter the hole easily and cut a thread.

The second tap is only tapered for about three threads and follows the first tap.

The third, or plug tap, is entered last and completes the operation, cutting the threads true to size for the whole length of the hole.

The two important things to be considered when tapping are the size of the hole, and the importance of entering the tap and tapping perfectly straight or at a right angle to the face of the work.

If you will study a screw thread for a moment, it will be seen that the smallest possible size of hole that may be used must be at least as big as the core diameter of the tap, which is only a hardened screw thread, fluted to make it cut. The larger the hole, the more imperfect will be the resulting thread.

Suggested tapping sizes may be found in the table at the end of this book. They will give a thread which is approximately 80 per cent. of the true form. This is quite suitable for most tapping jobs and may be cut without great difficulty.

Approximations to those sizes may be used if the exact size given is not available. For instance, tapping size for $\frac{3}{8}$-in. Whitworth is given as letter " N " but $\frac{5}{16}$ in. may be used, similarly for $\frac{1}{2}$-in. Whitworth, letter " X " is given, but 13/32 in. may be substituted.

If a drill size is used other than the size recommended, let it be slightly larger and not smaller.

The tap is rotated by a tap wrench.

The start of the thread will have a great influence on the finished tapped hole; if the first tap is not started perpendicular with the face of the work, the second and third taps will also be out of true.

It is advisable to take a backward turn after cutting about a third of a turn forward, this breaks off the chips inside the flutes which would otherwise hold so tightly to the tap that it would probably break.

Lubricant must be used except in the case of cast iron, which may be tapped dry.

A list of suitable lubricants is given on page 88.

Suppose it is required to tap a ½-in. Whitworth hole, then proceed in the following manner: —

First take a ½-in. diameter drill and drill until the full size has sunk about 1/32 in. below the surface of the metal.

Then take the *tapping size drill* letter "X" or 13/32 in. and drill the hole, turn the metal over and again with a ½-in. drill, drill 1/32 in. deep on the other side. The hole may then be tapped.

The advantage of this method is that a bolt or screw head will now sit down perfectly flat on the work.

If the thread extends for the whole thickness of the metal, a burr will be raised. When a bolt is entered, this burr will prevent two pieces of metal from being properly bolted flat together.

Few fitters serve the term of their apprenticeship without breaking a tap, and some hints on how to take out a broken tap will be given, but, as prevention is better than cure, some of the reasons why taps are broken may be first enumerated.

If the hole is *too small* the tap will most certainly break.

If the tap entered is at an angle, if too big or too small a tap wrench is used, if the taps are blunt, or if tapping without lubricant is attempted, trouble is sure to follow.

A tap of this form may be tapped right through the work. (Fig. 68.)

A tap of this shape may not! (Fig. 69.)

It is surprising how many artisans attempt to cut a tap like the one represented right through, when it is obvious

that where the tap thread ceases, unless the shank above it is smaller than the core diameter of the tap, it will only destroy the thread already cut or break the tap.

See that the tap wrench is a good fit on the tap shank. (Fig. 70.)

To extract broken taps may be a very tedious and difficult task.

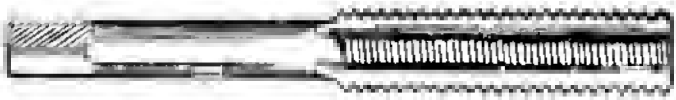


Fig. 68

If the tap is only entered a little way when it breaks, the broken piece may often be driven out from the other side by means of a soft punch.

If the tap is entered some distance when it breaks and the work may not be heated, a few drops of diluted nitric acid may be applied and left for several hours, after which the hole and tap are well washed with paraffin and the tap may generally be unscrewed.

If the work may be heated, using a gas flame, bring the tap to a red heat and allow to cool slowly in lime, when the tap will be soft and may be drilled out.

Before heating any work in which a tap is broken, get the permission of your superior.

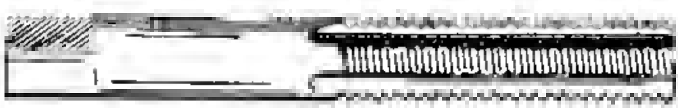


Fig. 69

Tap extractors are supplied in some factories, the simplest consisting of a rod having four flutes into which tough steel pins are inserted and held in place by a sleeve. These pins are fed into the flutes of the broken tap, secured by the sleeve, and when the rod is turned backward by means of a tap wrench (Fig. 71), the tap also will turn.

Before attempting to extract a broken tap, wash the hole

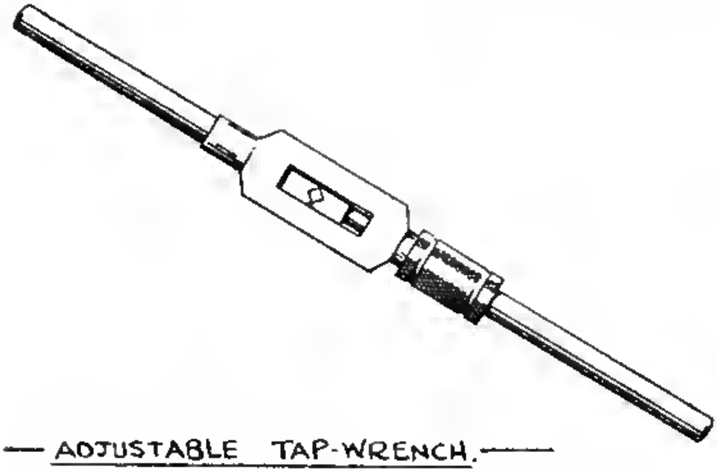


Fig. 70

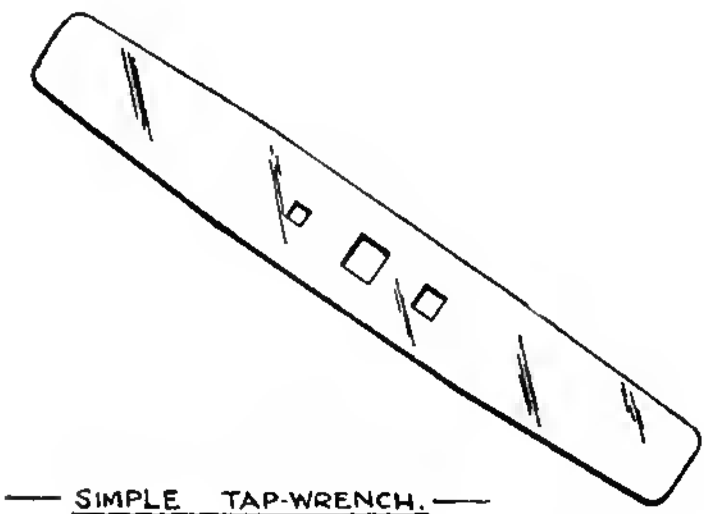


Fig. 71

perfectly clean with paraffin and clear any broken pieces of tap or swarf.

It has already been stated that extracting a broken tap may be a very tedious and difficult job, so the obvious thing to do is not to break a tap.

Internal threads are cut by taps, but external threads are cut by *dies*.

The most common die is the *spring die*.

It must be secured in the stock as shown, with the *centre screw* in the split. (Fig. 72.)

The first cut is taken with the die wide open.

Make the centre screw firm first and the other two screws afterwards.

Fig. 72

Then, having taken the first cut, release the centre screw and tighten up one of the side screws, when the die will be closed in and another cut may be taken and so on, until the thread is true to size.

Dies are tapered, and the side that has the size marked on, must be put in contact with the round bar to be threaded.

Lubricant must be applied.

The stock must be held square and a " lead " given to the bar either by means of a lathe tool or a file.

This lead must not be too abrupt ; 15 deg. approximately is quite suitable.

The lead must also be concentric with the bar.

Drilling and Reaming Lubricants

Tools	*Materials*	
	Mild Steel	Aluminium and Aluminium Alloys
Drills	Soluble Oil	Paraffin
Reamers	Tallow	Paraffin
Taps and Dies	Oil	Paraffin

CHAPTER XV

BLUE PRINTS

BEFORE a fitter can commence a job, he must have before him a picture of what he is asked to make, but as these pictures are not like ordinary pictures, some practice is required before the artisan can comprehend the different views shown on a blue print, and see in his mind's eye a picture of the completed work.

Since all solid objects have three dimensions, length, breadth and thickness, three views are given in a blue print called *elevation*, *plan* and *end view*. (Fig. 73.)

The elevation is the view of the article from the *front*.

The plan is the view of the article from the *top*.

The end view is the view from the *end*.

The outside cover of a simple matchbox is drawn below.

An engineer's drawing of the same matchbox would appear as in Fig 74.

Now take a matchbox cover and compare it with the drawing. The dotted lines at " A " indicate the thickness of the wood, while the dotted lines at " B " show *two* thicknesses of wood.

That this is correct may be clearly seen from the end view where the ends of the piece of wood from which the box is formed are folded together " C."

An experienced fitter would need to study the three views for only a very short time before a picture of a shape exactly like a matchbox would spring into his mind and he would begin to make it to whatever size and method of construction shown.

It will be noticed that the *plan* is drawn immediately underneath the *elevation* and the *end view* to the right of the elevation and in line with it.

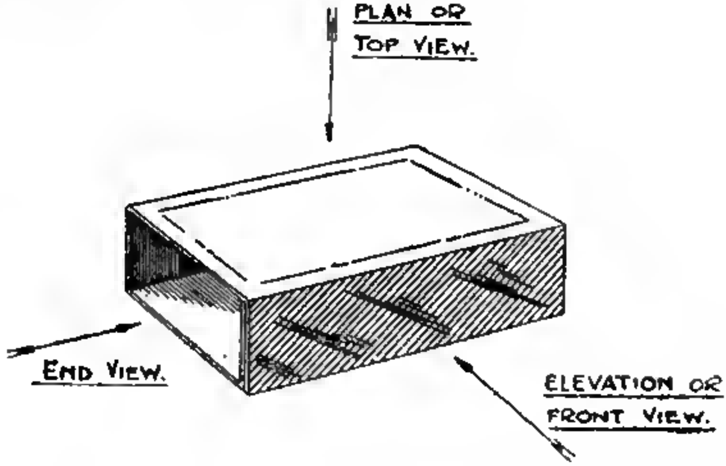


Fig. 73

The end view is what is seen to the left of the elevation and the *plan* is what is seen looking directly *above* the *elevation.*

To take another example, study the three sketches (Fig. 75) and see if the shape can be identified.

Again what is seen to the left is drawn on the right of the

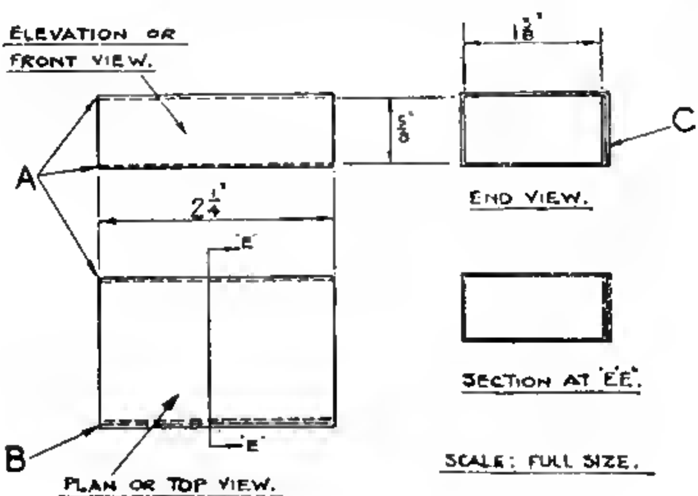


Fig. 74

elevation, and what is seen above is drawn below. The drawing is of the inside portion of a matchbox.

This system of projection is known as British projection or first angle projection, and in it each view of an object is so placed that it represents the side of the object remote from it in the adjacent view.

In the American system of projection, or third-angle projection, each view is so placed that it represents the side of the object *near to it* shown in the adjacent view.

First angle projection only will be dealt with here.

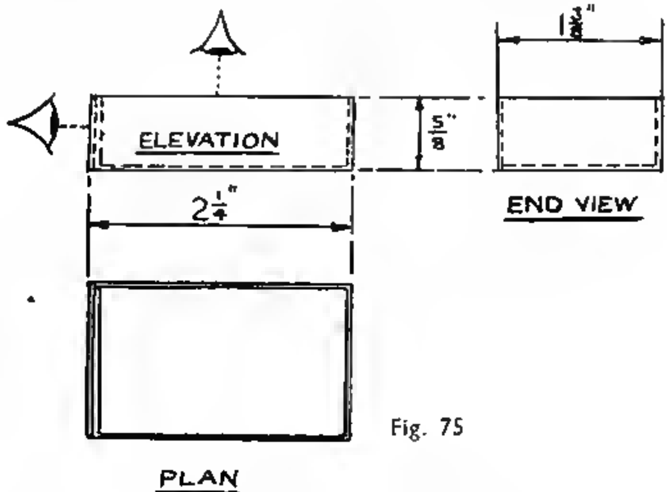


Fig. 75

Now examine again the engineer's drawing of the outer cover of a matchbox. (Fig. 74.)

Notice the *short* lines indicating the thickness of the wood which cannot be seen but are known to exist.

Notice also that the *contour* or *shape* on all views is shown by a hold thick line.

See also that dimension lines giving length, breadth and thickness are thin lines.

If the matchbox were to be cut in half and a view from a position looking directly at the cut half were drawn (*see* E—E, Fig. 74) that would be a *sectional view*, and the fact that it was a sectional view would be shown hy lines drawn at 45 deg.

Sectional views are very often employed to show what a piece of work would look like if it were cut open so that you may see inside.

Suppose a flat portion had to be machined or filed on a round bar, then it would be shown as in Fig. 76.

The irregular boundary line indicates that only a portion of the full length of the bar is drawn.

Two common methods of showing shortened bars are drawn below the example.

A line composed of dots and dashes is the *centre line.*

We have now proceeded far enough to consider a typical engineer's blue print in detail.

The object chosen for demonstration is a *jack* used to raise or lower work to the required height.

Three views of the body and a sectional view are shown in Figs. 77, 77a, 77b.

The screw is shown separately and an *assembly drawing* shows what the work is like when finished.

Two views only are shown of the screw and two views only are really necessary to show all details in the body, but three views are shown to avoid confusion.

Note the dotted lines indicating the hidden detail such as the screw thread, the recess to clear the screw shank beneath the head at " A " and the recess to clear the tap at " B."

The base is also recessed so that dirt may not prevent the jack from lying flat.

Note the abbreviations :—F and G, " F " means " face " by machine or file, and " G " means grind.

C.S. means cast steel, and M.S. mild steel.

Notice also the *centre line.*

Other common abbreviations are :—D.F.—driving fit, S.F. sliding fit, M/c—machine, r—radius, Csk—countersink, Cshdn and Gr—Casehardeu and grind.

℄ Centre line : Cpt—component, Swg—means standard wire gauge, so that if, say, 18 s.w.g. mild steel were specified, consulting the table at the end of the book, under the heading " standard wire gauge," No. 18 will be found to be .048 in. thick, so you would have to use mild steel .048 in. thick.

If a pin had to be driven into a hole so that it became tight,

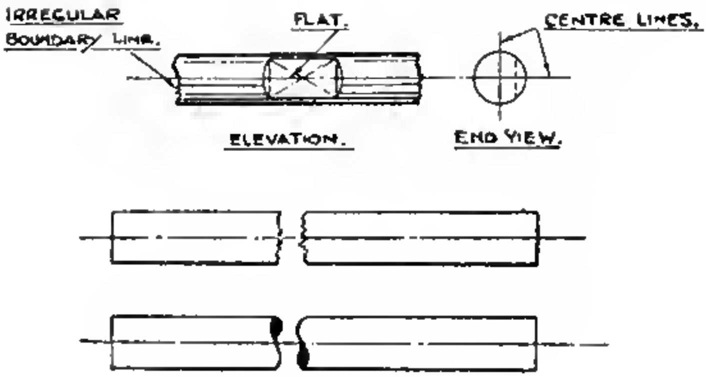

IRREGULAR BOUNDARY LINE.
FLAT.
CENTRE LINES.
ELEVATION.
END VIEW.

Fig. 76

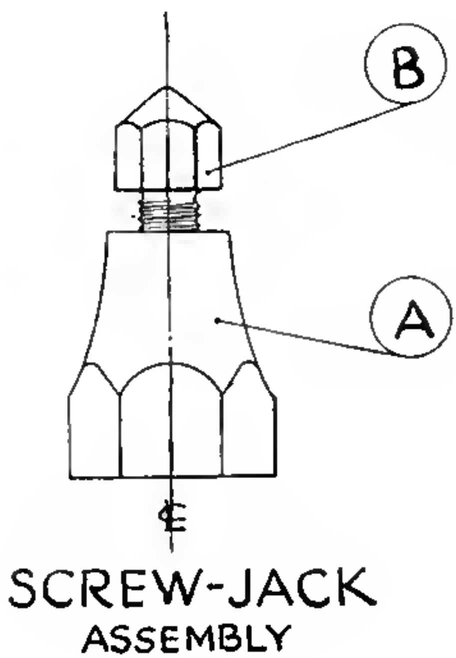
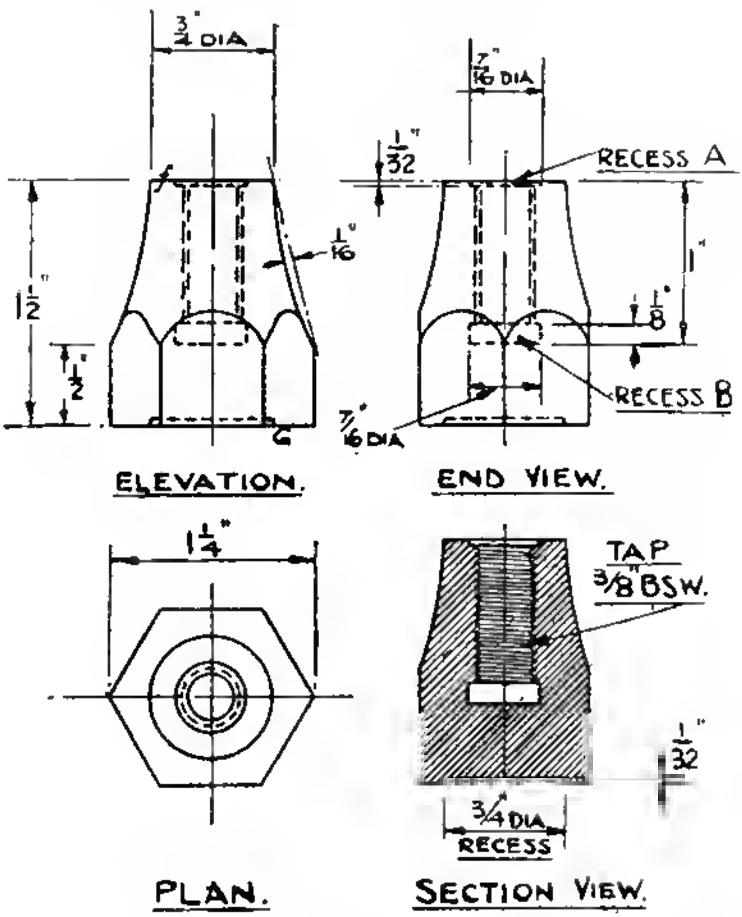

B
A
SCREW-JACK
ASSEMBLY

Fig. 77

that would be a driving fit, on the other hand, if the pin had to be fitted into a hole so that it could be turned, and yet the difference in size of hole and pin could not be enough to allow "play," a sliding fit would be required.

The abbreviation for caseharden and grind will be fully understood when the chapter on hardening and tempering has been studied.



PART "A". BODY

Fig. 77a

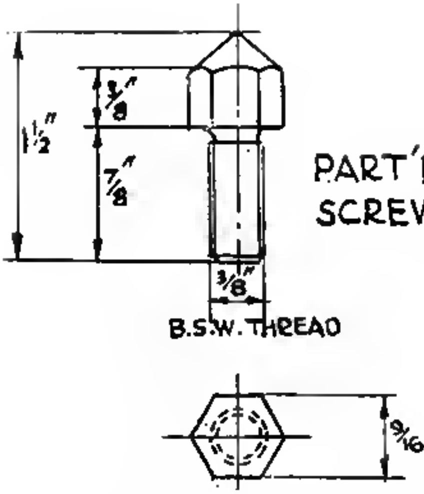


Fig. 77b

A component is a part of a piece of work which is placed in a jig to be drilled, tapped, machined or reamed.

T.P.I. means threads per inch.

P.C.D. means pitch circle diameter.

Drawings are made to scale.

If a drawing is made with all the parts the same size as the actual finished pieces, the *scale full size* will be written on it or 1/1 meaning the same.

If the scale is half size, then this will be shown either by the words *half size* or " ½," which means half size.

Scale is only given to give the workman an idea of the finished size of the work and so that the drawing will be uniform.

The size of the drawing is not necessarily exactly the same as the size written on the blue print. Whatever size is written, that is the size.

A scale must never be applied to a drawing to take a dimension. If the dimension is not shown, then report the error to a responsible person.

In the example (Fig. 78), a job consisting of two parts only is shown.

Each part of the work is drawn separately.

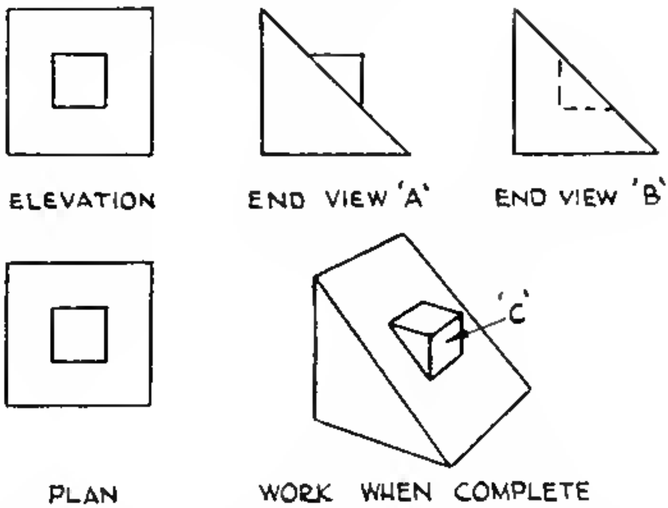


Fig. 78

The usual practice is to give each part a letter and then in the *assembly drawing* indicate the position of the part by the same letter.

This is very helpful to the fitter, as it assists him to get a clear idea what the finished work is like, and it is foolish to commence work unless the drawing is sufficiently understood.

Few fitters can look at a drawing of any size and immediately understand what is required.

The drawing must first be studied closely.

Time spent studying a drawing is never wasted.

In the drawing example previously given, only two views were necessary for all details.

Drawings will now be considered in which a third view must be shown.

Study the elevation and plan of the drawing in Fig. 78. At least two-thirds or end views are possible as shown at " A " and " B."

A drawing of the completed work is given. Notice that " C " is required to protrude and not recess. End view decides this.

Again examine the two views of a cross (Fig. 79).

It is intended that the fitter's finished work is of the shape

of a cross, but unless the end view were given, then the fitter could make a shape as shown at "X" and still be correct to drawing.

The importance of the end view is thus clearly demonstrated.

The fitter is advised to take every opportunity of studying blue prints.

If the principle is understood, then the art can be mastered speedily by practice.

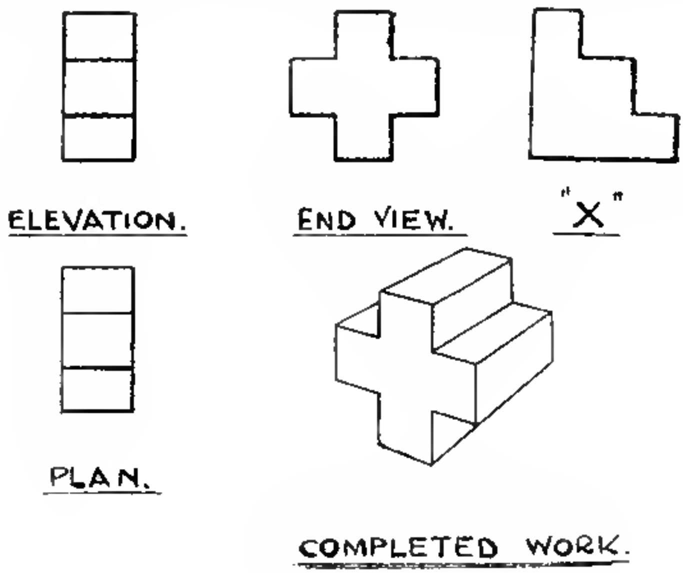


Fig. 79

CHAPTER XVI

HARDENING AND TEMPERING

THERE are so many kinds of steel that it will take many pages of this book merely to give their names.

There are steels which may be hardened and steels which may not ; that point is the chief consideration in this chapter.

A fitter uses so many instruments which have to be hardened that without an elementary knowledge of hardening and tempering he would be severely handicapped.

Scribers, centre punches and chisels, for instance, must be hardened and tempered.

Hardening means making the steel as hard as it will possibly become by heating to a red heat and plunging in oil or water. *Tempering* means reducing that hardness to a *degree* of hardness known to be most suitable for the instrument being made. Steel containing carbon from .6 per cent. to 1.6 per cent. is capable of being hardened. Carbon exists in steel in many forms, but for the purpose of explanation we will consider two forms, pearlite and martensite. When the carbon is in the pearlite form the steel is soft, when, however, the steel is heated above a point known as *its critical temperature* the form of carbon changes from pearlite to martensite, and if the steel is immediately plunged into oil or water the carbon is trapped in this condition and the steel becomes hard. At this stage the steel is brittle and will break under a blow or heavy pressure. To make it suitable for use it must be "let down" or "tempered" and brought to a condition known as its "sorbitic state." This tempering process is obtained by reheating the metal to a degree depending on the type of instrument being made, whether it must withstand a blow like a centre punch, pressure like a scriber, or be capable of being sharpened to a keen fine edge like a razor.

Hardening and tempering which are carried out with modern equipment, where the hardening and tempering temperatures are accurately controlled, is, of course, far better than any method which depends on guess work, experience and judgment. Hardening and tempering of small tools, however, can definitely be accomplished by the fitter if he will use his eyes and common sense, together with the rudiments of the business.

It is to be assumed then that no modern equipment is at the disposal of the fitter, and that his means of heating the steel is either a gas flame or a blacksmith's forge. Consider, for example, a centre punch that has to be hardened and tempered. The punch is made of cast steel, that is, steel capable of being hardened, and not of mild steel, which can only be given superficial hardness by special treatment.

The procedure is—light the gas flame and adjust the air inlet so that a good surface of flame plays on the brick or coke. Place the punch in the flame by means of a tongs. Get it hot *gradually* and let the hottest part of the flame be on the thickest part of the punch.

As stated elsewhere the pointed end of the punch only is to be hardened, so see that only this end becomes red hot. Turn the punch over occasionally by means of the tongs so that the heat penetrates evenly.

When a red heat is attained, plunge the punch *vertically* into cold water.

Now take a file, and holding the punch in one hand and the file in the other, attempt to file the hardened part. If the file slips off, the punch is hardened, if the file cuts the steel, then the punch is soft and either you are not using cast steel or the steel has not been made hot enough.

Assuming the punch is hardened, the next step is to temper it. First take emery paper and thoroughly clean the hardened end until it is bright, now adjust the gas flame until only a short narrow flame is obtained. Play this flame on the *soft* end of the punch and presently colours will be observed moving down the polished surface of the hardened end.

The first colour will be light yellow. Continue to heat the punch until the colour changes through different shades of

yellow to light purple. Then again plunge the punch vertically in water and the hardening and tempering are complete.

The punch may be ground and is ready for use.

Generally speaking, the hardening process is the same for all fitter's tools, only in tempering is the treatment different.

The colours at which to temper the following tools are given below :—

Scribers and dividers—Light straw.

Drills and punches—Light purple.

Chisels—Dark purple.

Screwdrivers and springs—Blue.

Oil is a better hardening medium than water. Quenching in water is often too severe and causes cracks to appear in the work.

A good way to raise the tempering heat in the tool is to lay it on a piece of scrap steel which has been previously heated to a dull red. Hot sand is better but requires a little more trouble.

Mild steel cannot be hardened in its natural state.

Where a hard surface is required, a hard skin can be produced by means of *casehardening compounds*.

These compounds introduce carbon into the steel for some small depth enabling that part to be made hard.

The following system is used to caseharden small parts.

The parts are first placed in a cast-iron box containing hardening compound. They must be spaced so that no two parts touch and the compound must completely cover each part.

The box is then sealed, placed in an oven and brought to a red heat.

This heat may be maintained for a period varying from eight to twelve hours. The carbon has then penetrated from .015 in. to .025 in. deep into the steel.

The box is taken from the oven and allowed to cool slowly.

The parts are then said to be *carburised* and, although containing enough carbon necessary for hardening, they are still soft and may be drilled and machined. To harden the parts, they must be brought to cherry-red heat and plunged into water. They will then have a thin hard skin, although

inside, of course, the mild steel is still soft. It is good practice to include piece of scrap steel in the box which can afterwards be hardened and broken. The depth of carburisation can be seen quite easily at the fractured ends.

Casehardened mild steel pieces can be straightened after hardening if the bend is not too severe, but cast-steel pieces will break if it is attempted to alter their shape cold.

Another system of casehardening is the *cyanide bath.*

The parts to be hardened are suspended in a bowl of molten potassium of cyanide and left for half an hour, after which they are plunged into water.

A hard skin approximately .005 in. deep will have formed.

When hardening cast steel, the following points must be watched :—

The steel must be heated slowly. It is best to leave the job near a fire or oven for some time before hardening, to allow the heat to *soak* through the metal. In addition, the piece must be turned in the flame to give equal heat to both sides.

If the metal is heated quickly, the centre is cold and the difference in temperature causes the steel to crack.

The heat must be applied continuously and the temperature made to rise constantly.

The job must not be allowed to burn.

Sharp points and thin sections should be cooled in oil while the thick part is gaining its temperature.

Water must not be used ice cold when dipping cast steel or cracks will be caused.

Another cause of cracks is gripping the hot piece with cold tongs.

The work must be immersed quickly and vertically.

CHAPTER XVII

OILSTONES AND GRINDSTONES

WHEN a scriber or divider is ground on a grindstone, the point is not a true sharp point, but a ragged point, because the rough grindstone leaves it so ; it must, therefore, be finished on an oilstone.

The machinist also creates a smooth edge on his tools after grinding by rubbing on an oilstone.

Small hand oilstones of various shapes are used by the fitter for putting a smooth sharp cutting edge on dies and forming tools. In fact, an oilstone is such an indispensable part of workshop equipment that it deserves a chapter to itself. Yet many fitters, through lack of a little simple knowledge and common sense, abuse oilstones daily without realising that they are doing so.

Oilstones are of two kinds, natural and artificial.

A natural oilstone, which is cut from the hillside and formed to a convenient shape, is much more serviceable and expensive than an artificial one.

Artificial stones are made of small particles of grit which are mixed with some bond or joining compound and baked in an oven at a great temperature until the whole mass becomes united.

Most natural stones come from Canada, among these are the " Washita " and " Arkansas." The Arkansas, a white greyish-looking stone, is probably the best for all round work.

Another well-known oilstone, the Turkey oilstone, is quarried in Asia Minor.

Oilstones should be kept clean and moist. Allowing them to remain dry a long time or exposing them to the air for long, tends to harden them. A new stone should be soaked in oil for a few days before use.

The stone should be provided with a cover and a few drops of clean oil placed on it from time to time to keep it moist. Oil should be used liberally.

Oil, besides making cutting easy, prevents the fine particles of steel cut off by the stone from filling the pores and causing glazing.

After use, the steel chips from the sharpened tool are floating in a film of oil and if not removed will settle and fill the pores of the stone.

To prevent this, dirty oil should be wiped off the stone as soon as possible after use and the stone cleaned with paraffin.

If the stone should become glazed, it can be cleaned with petrol or ammonia, or scoured with emery or a piece of sand-paper fastened to a board.

The best thing with which to apply the petrol or ammonia is a piece of cotton waste.

To scour with emery, first get a flat cast-iron block and spread on this emery powder and water. The stone may then be rubbed until it becomes true, replenishing the emery and water when necessary.

A quick way to restore an even flat surface to an oilstone is to grind it on the side of a grindstone.

Beginners have a tendency to create grooves in an oilstone by rubbing points of scribers and dividers backwards and forwards in one place. This must be avoided, as also must the practice of using the middle of the stone all the time, instead of using it evenly all over the surface.

Grindstones

In modern machine shop practice, it is usual for all grinding operations to be done by men whose sole job is grinding. Nevertheless a knowledge of grinding wheels is useful.

As with oilstones, there are natural and artificial grinding wheels.

Natural wheels cut better if water is used during the operation, but the wheel must not be left with water in contact with the bottom of the wheel or that portion of the wheel will become soft and wear away quicker than the rest, causing the wheel to become uneven.

Artificial wheels are used extensively.

Wheels have *grit*, *grade* and *structure*.

Artificial wheels are composed of two essentials, the "abrasive" and the "bond."

The abrasive is the small particles of cutting material which do the actual grinding.

The bond is what holds the abrasive particles together.

"Grit" is the small hard particles which do the cutting, and are designated by number. These numbers are obtained in the following manner: First the pieces of hard cutting material are crushed and then passed through a number of sieves, each sieve having a certain number of holes to the linear inch. Thus, say, if a grit will pass through a sieve having eight meshes to the inch but will not pass through a sieve having ten meshes to the inch, it will be a No. 8 grit.

The sizes range from about No. 8 up to No. 120. No. 8 will obviously be coarse and No. 120 comparatively fine.

"Grain" is the degree of hardness of the wheel, that is to say, the tenacity with which the bond holds the abrasive together.

Soft wheels release their abrasive quickly, but hard wheels release the abrasive much more slowly.

A wheel may contain a very hard abrasive and yet, because it releases that abrasive quickly, may be a very soft wheel.

The structure of a wheel is the spacing of the grit, that is, the distance between the pieces of grit.

Wheels wherein the grit is widely spaced are known as "open wheels."

Wheels in which the grit is close together are "close wheels."

A few more points relating to the surface grinding machine and the tool grinding machine:—

When wheels become glazed or out of shape through use, their true shape and cutting properties are restored by means of either a "diamond" or a "wheel dresser."

The diamond is used for fine wheels on the surface and cutter grinding machines.

The wheel dresser is used to true up tool grinding wheels.

The amount of cutting area on a surface grinder is approxi-

mately a straight line. Consequently the whole width of the wheel must be in contact with the work.

To true up the wheel, fasten the block which holds the diamond on to the magnetic chuck and pass under the centre of the revolving wheel. Only a very small amount should be cut off each time.

Goggles should be used during the operation, as the small flying particles of wheel are a danger to the eyes.

Do not attempt to true the wheel holding the diamond in the hand, as this is not only dangerous, but results in an uneven cutting surface which quickly wears away and glazes.

When a wheel is glazed, it begins to burn the work and dull red sparks appear. The wheel must immediately be trued by the diamond.

When mounting a wheel on either the surface or tool grinder, make sure that the hole in the wheel is a good fit on the machine spindle. A wheel that is " forced " on to the spindle is dangerous.

There should be a suitable washer on both sides of the wheel and in between the washer and the wheel a piece of blotting paper.

If the surface grinder has a magnetic chuck, remember that all metals are not magnetic. Brass, for instance, cannot be held by the magnetic attraction of the chuck.

Tool grinding machines have a rest supplied to support the drill or whatever tool is being ground. The rest should be close to the wheel to prevent the work being drawn down between the wheel and the rest.

It is bad practice to grind soft metals such as brass on a grindstone, and, although convenient, grinding pencils is harmful to the stone.

Speed is another important factor. It is dangerous to put a wheel on a machine of a greater diameter than the machine is intended to carry. A little mathematical consideration will show that the surface speed in feet per minute will be increased and the wheel may burst.

Speeds for grinding wheels for different purposes may be obtained from tables.

If it is your job to change wheels, take note of the wheel diameter, thickness and the size of the spindle hole.

The grit is designated by a number, the grade by a letter.

With "Universal" and "Norton" wheels, the letters at the beginning of the alphabet denote the softest grade wheels. Those at the end, the hardest.

So, a wheel of grit 46, grade M, would be a wheel of medium grit and grade. Conversely with "Carborundum" wheels "E" is very hard and "U" very soft.

Use the wheel evenly, moving the work across the whole face during the grinding operation and avoid pressing the work on one place.

CHAPTER XVIII

KEYS AND KEYWAYS

CUTTING a keyway in a shaft or wheel hub by hand is a very skilled job, and the artisan performing the task for the first time must have all his wits about him and a little more than usual skill to make a success of it.

Whenever possible keyways are cut by the aid of machine tools. A milling machine may be used on a shaft and a slotting or shaping machine on a wheel hub.

Circumstances, however, are not always favourable. For instance, a milling, slotting or shaping machine may not be available, or perhaps, it is not possible to remove the shaft from its position. In such cases the fitter is asked to perform the operation by hand, and the purpose of this chapter is to show him how to do it.

First a word about key dimensions. Because in practice the same sized key is used for shafts of different diameters within a certain range, it is not possible to give an exact formula for key size in terms of shaft diameter.

An approximate formula however is :—for square parallel and square taper keys, width and thickness = quarter of shaft diameter. For rectangular parallel and rectangular taper keys, width = quarter of shaft diameter, thickness = two-thirds of width.

According to British Standard practice, the depth of keyways in shaft and hub are so dimensioned that the key sits half in the shaft and half in the hub when measured at the sides. This is clearly shown in Fig. 80, and the rule applies to almost all sunk keys. Different kinds of keys are shown in Fig. 81.

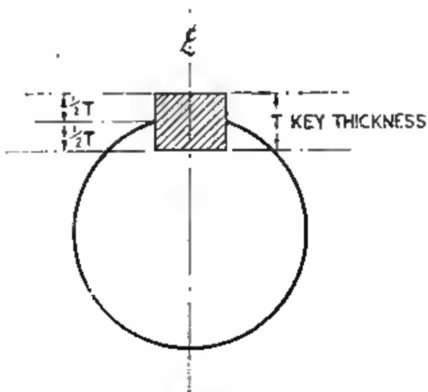
There are square and rectangular parallel keys.

Square and rectangular taper and gib keys.

The gib is useful for driving the key in or for pulling it out, but it cannot be used in positions where there is any danger of it catching the clothes of workpeople.

A taper key will be half in the shaft and hub at its large end.

Gib keys are half in shaft and hub where the gib radius blends into the taper. In practice they are seldom driven into the hub as far as this, and it is preferable that there is some clearance between the hub face and the radius on the gib.



FLAT SUNK KEY
Fig. 80

Saddle keys are used when there is little power to transmit.

Flat keys are sunk into the hub only and bear against a flat on the shaft. The flat is as wide as the key.

A feather key is a rectangular or square sunk key that is a tight fit on the shaft keyway, and a sliding fit in the pulley keyway. This kind of key is used when a pulley or gearwheel has to slide along the shaft and transmit power at different positions.

Two other types of keys are shown in Fig. 81.

The first shows a key in a tapered shaft end. It will be noticed that the end of the shaft is threaded to take a nut which is used with a washer to force the wheel hub tight up on to the taper. The hole in the hub, of course, is bored to the same taper as the shaft.

The correct name for this type of keying is ." coned and

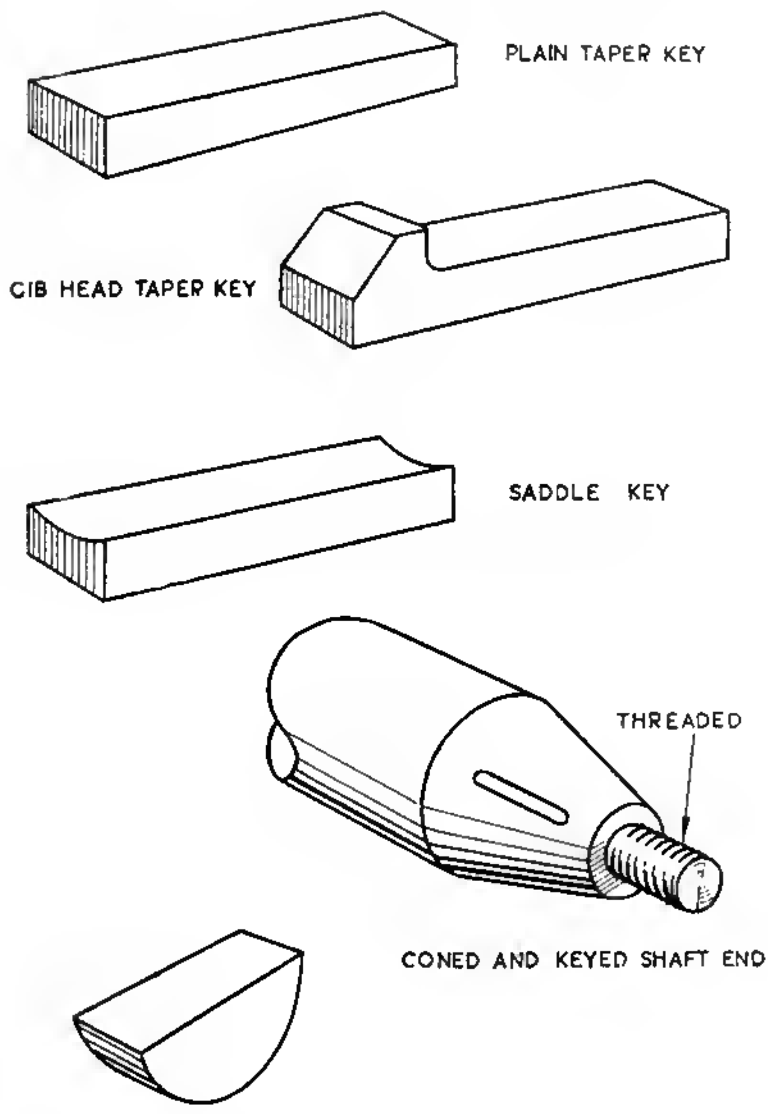

PLAIN TAPER KEY
GIB HEAD TAPER KEY
SADDLE KEY
THREADED
CONED AND KEYED SHAFT END
WOODRUFF KEY

Fig. 81

keyed " shaft end. Either square or rectangular keys may be used, and the keyways are cut parallel to the tapered shaft face.

Woodruff keys. The advantages of Woodruff keys are that they are easy to assemble ; the key slots are rapidly and easily machined, special cutters being obtainable to cut the circular key slot ; they require little or no fitting time and, as a rule, are easily extracted. When fitting the keys, however, it is recommended that the corners where the radius meets the flat are removed, as they sometimes dig in and cause difficulty if left sharp.

" Fit " of Keys

Straight sunk keys both square and rectangular should be a good tight fit on the sides and clear on top.

Sometimes with this kind of key screws tighten down on to the key through the wheel hub.

Taper and gib keys should bear firmly on bottom, top, and sides. If properly fitted they can be relied upon to prevent endwise as well as rotary movement of the wheel on the shaft.

Saddle keys and flat keys bear heavily between shaft and hub throughout their length.

Feather keys are a tight fit in the shaft and a sliding fit in the hub keyway.

Coned and keyed shaft ends. The taper on the shaft fits tightly up against the taper in the pulley, and the key is tight on the sides and clear on top. Clearance on top of a key need be no more than .010 in.

Woodruff key. The key is a tight fit in the shaft and an easy fit in the pulley keyway. If the machining is done properly, and the key itself made to standard tolerances, very little or no fitting is necessary.

When a Woodruff key is used there must be some factor other than the key to prevent endwise movement of pulley or gearwheel.

The edges of all keys are slightly chamfered to clear the almost unavoidable small radius at the bottom of the keyway. A keyway must be an equal distance each side of the shaft and hole centre line. The sides must be square and parallel to the

centre line, and the bottom of the keyway must be flat.

For a taper key the bottom of the keyway in the shaft is parallel to the shaft surface, and the top of the keyway in the hub is tapered.

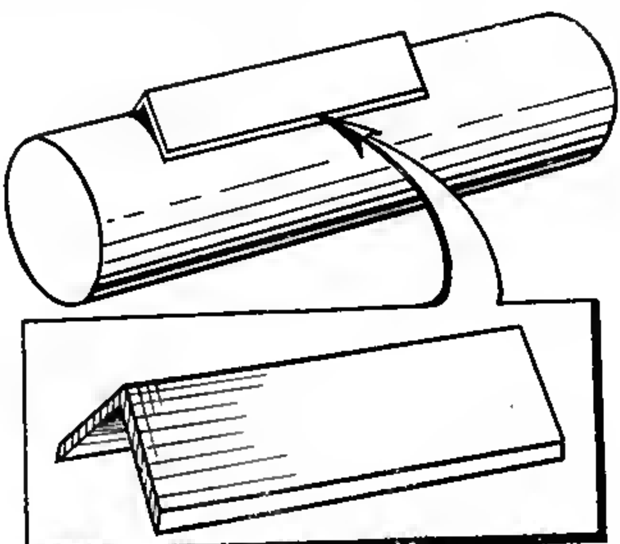
The British standard taper is one in one hundred. An alternative taper of $\frac{1}{8}$ in. to the foot is sometimes used.

A keyway must run true in the shaft throughout its whole length. That is, it must be a straight groove and not a spiral groove.

How to Cut a Keyway in a Shaft

Let us first assume that we are faced with the most awkward circumstance, that is: the shaft cannot be taken to a machine and we have to cut the keyway by hand. The keyway has therefore to be cut by means of hammer and chisel and finished off by filing.

First the position of the keyway must be marked out on the shaft using a box square, or key-seat rule (Fig. 82). Since the



BOX SQUARE

Fig. 82

latter is used in exactly the same way as the box square, the box square only will be dealt with.

This is quite a simple tool to use. It is held firmly on to the shaft by one hand, and a line scribed along either of its bevelled edges will run true and parallel to the centre line of the shaft.

Any size of box square can be used for many different sizes of shaft, but when the shaft is so small that the faces of the square and not the bevelled edges come in contact a smaller square must be obtained.

The better type of box square has one leg shorter than the other and is generally divided into inches, tenths, etc., so may be used to mark off the length of the keyway.

Work on top of the shaft, if possible. Clean the shaft and apply copper sulphate.

Take the box square and, pressing it firmly on the shaft, scribe a clear centre line. Let the line be longer than the keyway has to be.

Make a light punch mark at each end of the line.

Now to mark the width of the keyway. Take a distance equal to half the width of the key in your dividers and scribe semicircles each side of the centre punch marks.

The box square is now brought up tangential to the arcs, held firmly in position, and the sides of the keyway marked on in turn.

The width of a key slot marked in this manner will be a little less than true size, but the difference is usually small enough to be ignored.

The keyway length may now be marked. Lay a rule on the centre line and tick off the length with a scriber.

The ends of the keyway have now to be scribed on.

A piece of thin steel shim is useful for this purpose provided one edge is straight and the piece is long enough to pass completely round the shaft.

Pass the shim round the shaft bringing the two ends together. The true edge of the shim may now be placed at the correct position, and the ends of the keyway marked in turn.

If the two ends of the true shim edge are held quite level, the edge of the shim will be square across the shaft.

An alternative method of marking the keyway ends is to get someone to hold the box square firmly on the shaft. A thin steel rule may now be pushed against the box square end and bent to the shape of the shaft by hand pressure. It is an easy matter to scribe along the rule edge.

Put small centre-punch marks all round the keyway.

The centre-punch marks are witness marks and must be carefully positioned.

If the punch point is held lightly on the shaft and drawn over the line until it is felt to have dropped in, more accurate positioning will result than if it is attempted to find the line by dropping the punch on to it.

Take special care to put a punch mark at each corner, the reason for this will be obvious later on. The key slot is now clearly marked for length and width and the serious business of cutting it out may be commenced.

The tools required first of all will be: two chisels, one flat and one diamond, a hacksaw, and a half-round second-cut file.

First cut the slots with the hacksaw down to just about the lines, and a fairly even distance apart as shown in Fig. 83.

Next take the flat chisel, trim off the ridges of metal and blend the ends in to a shape shown in (*b*, Fig. 83.) Smooth up and finish true to the lines with a file, leaving a full line in.

We have now got a flat almost the length of the keyway having radiused ends. Assuming that the keyway may be longer than the key, the ends of the keyway may sweep down at an angle to the bottom of the keyway. This condition gives full play of the chisel and file, and allows room for a drift if the key has to be driven out. The flat at the bottom of the keyway, of course, must be longer than the key.

Now take the diamond chisel and cut grooves into the flat longitudinally, as straight and as near to the same depth as your skill permits (*c*, Fig. 83).

Next use the flat chisel, which should be a little narrower than the width of the keyway, and cut out the grooves. Take only light cuts, and take care not to dig into the sides of the keyway.

Continue this process until the depth of the slot is about 1/32 in. short of full depth, allowance being made all the time

for the ends of the keyway to sweep in at an angle, and leaving approximately 1/32 in. of material at each side.

At this stage carefully file across the whole length of the keyway until the lines and punch marks are filed half away.

This operation is most important and must be carefully done because the edges left after filing will be the datum lines from which to work with the depth gauge, and if they are

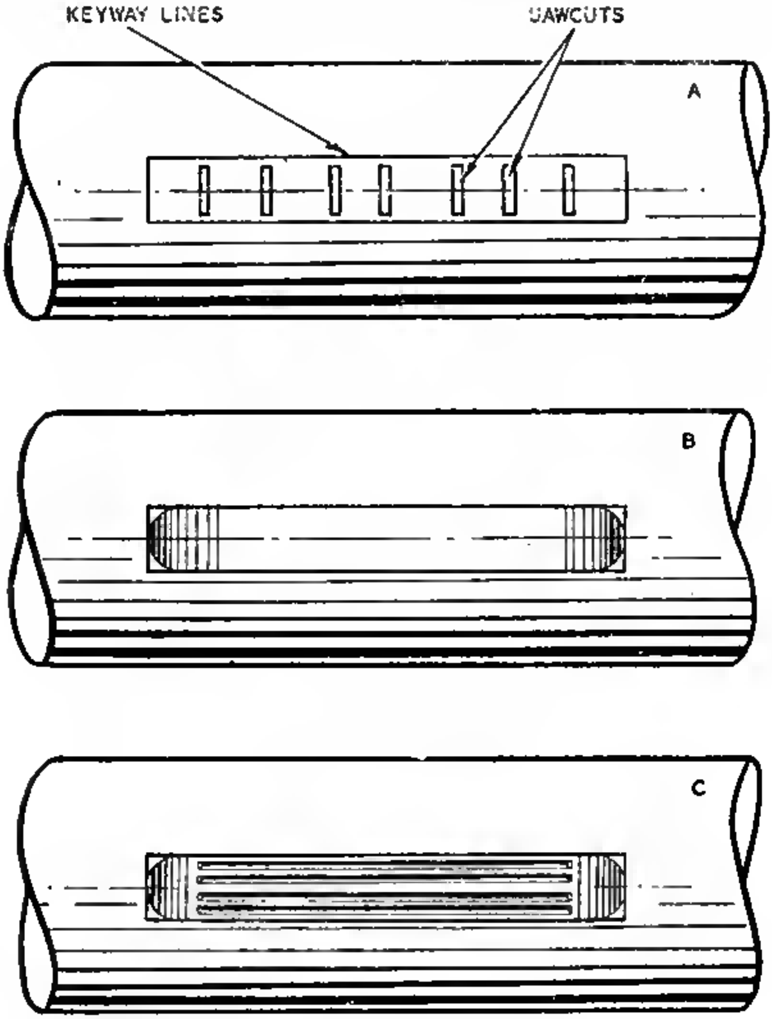


Fig. 83

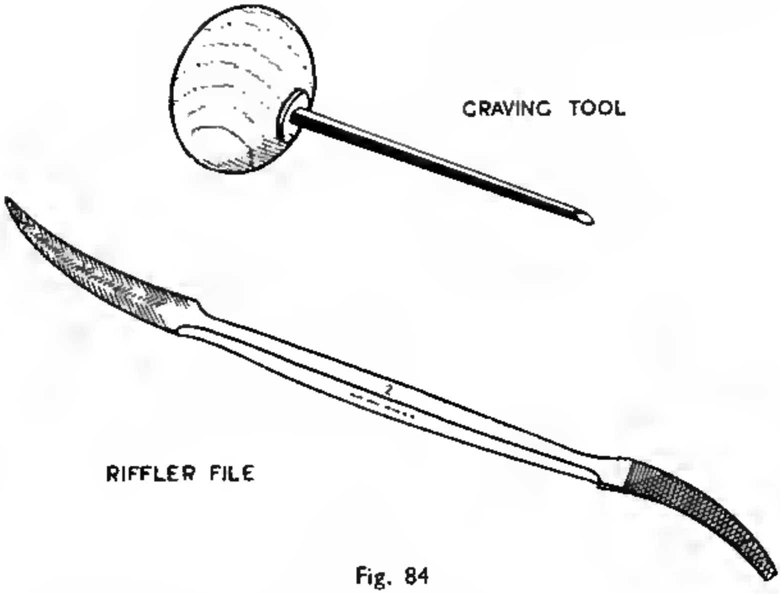


Fig. 84

incorrect the sides of the keyway will not be true with the shaft centre line.

After each successive use of diamond and flat chisels on the flat portion of the keyway, blend in the ends and true up the bottom, using a rifler or bent file (Fig. 84), or a file of suitable section bent in the shape of a dogleg.

The final operation is all filing, testing for depth all along the keyway with a depth gauge and taking great care that the sides are filed square, that is, at right angles to the keyway edges. The small radius left at the bottom of the keyway sides may be taken out by means of a graving tool. (See Fig. 84.)

When the key slot is almost the full width, the key itself may be used as a gauge. It must not be forced in, but only lightly tapped with some soft implement such as a piece of copper or hard wood.

Mention has already been made of the small chamfer along the edges of the key. This chamfer will act as a " lead," and if the key is placed flat on top of the keyway slot, which is nearly to size, and tapped lightly, the key will sink in a little way. Remove the key by levering it out and the high spots in the keyway will be clearly seen.

These high spots may be filed off, and, by repeated trial, the key will gradually sink firmly into the keyway. The key must be fitted in this manner throughout the whole length of the keyway.

The fitter will use all his skill and attention on the work. He will enter the key for test as few times as possible. He will avoid burring the key, or " belling " out the keyway by the application of too much force.

If a taper key is to be fitted, the bottom of the keyway must not only be flat, but as near parallel to the shaft horizontal centre line as possible. If it is not so, the work of fitting the key correctly into the hub keyway will be increased. To make sure the bottom of the keyway is flat, take a spare key or piece of stock of the same length and reduce its width .002 in. to .005 in. less than the key.

Put blue on the surface-plate and scrape the bottom of the key or stock, flat and square to the sides. The piece may now be blued on the scraped side, and used to rub on the bottom of the keyway for comparison, the high spots on the keyway bottom being scraped off until flatness is attained.

Cutting a Key Slot, using a Drilling Machine

If we can remove most of the material from the key slot by means of a drill, the work will be considerably simplified.

It does not matter whether we take the shaft to the drilling machine, or the drilling machine to the shaft, the procedure is very much the same.

Portable drilling machines are generally available in marine work, for example.

The first steps concerning the use of a box square for marking out the shaft have already been explained, but if the shaft can be placed on " vee " blocks on a suitable flat surface the keyway may also be marked out by means of a surface gauge or a height gauge. It is important that the shaft be perfectly horizontal to the surface on which the " vee " blocks rest.

If it is a long shaft, it should be supported by timbers and packed up until horizontal and flat down on the " vee " blocks.

Having marked out the keyway it may be gashed with a

hacksaw, the surplus arc of metal cut off, and the ends blended in as before. A flat surface is thus obtained on which to mark the position of the holes to be drilled, and there will be little tendency for the drill to " wander " as would be the case if it was attempted to start drilling holes on a radiused surface.

Cover the flat surface with copper sulphate. Take dividers and, picking up the small centre-punch marks on the corners of the keyway, describe arcs to intersect. Join up the intersecting points and the centre line is accurately placed, Fig. 85.

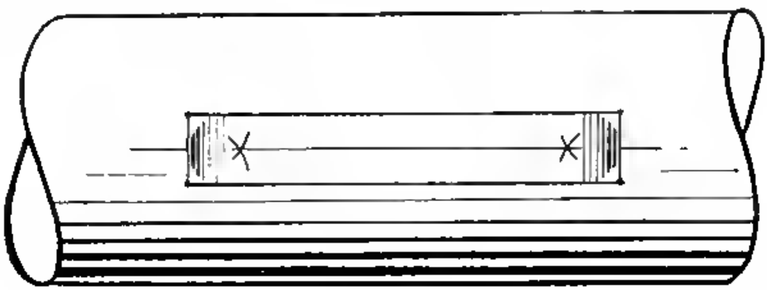


Fig. 85

If the shaft is to be drilled on the drilling machine table, use a drill 1/32 in. smaller than the width of the keyway, but if the drilling machine is to be taken to the shaft use a smaller drill still. When the key width exceeds $\frac{5}{8}$ in., leave more than 1/64 in. of material each side of the drill and drill a small pilot hole first.

Mark out the hole positions carefully so that the holes just fail to break into each other. A little extra care and attention to this detail may save a lot of hard work later on.

Describe circles round the hole centres and put four witness punch marks. The holes will be drilled to a depth about .020 in. short of the finished depth. Ignore the ends of the keyway ; they can be blended in easily afterwards.

Before drilling, set up the shaft on " vee " blocks on the machine table and, using the surface gauge, set the edges of the keyway to exactly the same height.

Clamp down the securing screws and check again.

If a straight-shank drill is used, lock it up tightly in the

chuck with the chuck-key, otherwise vertical movement of the drill in the chuck will take place, spoiling the setting.

An ordinary type of depth gauge will not indicate the depth to the drill point. Remember this and make provision for it.

Drill all the holes, setting the drill stop for depth after the first hole is drilled.

Next take a flat-bottomed drill and drill the full depth less .020 in., setting the drill stop again after the first hole is drilled correctly. Finish off the keyway with chisel and files.

Two methods of cutting keyways in shafts have been shown, and any difficult keyway may be cut by the appropriate method. The circumstance wherein one or the other method cannot be employed will be very rare.

How to Cut a Keyway in a Hub

The first consideration is to mark off the keyway in the hub.

When the keyway is longer than the wheel hub, the following simple method may be used.

First prepare two short pieces of steel (two pieces from a spare key will do), make them a sliding fit in the shaft keyway, and file one end square to the bottom and sides. Push the hub into such a position that an equal amount of shaft keyway shows at each side.

Now take the two pieces and press one piece into the shaft keyway at each side of the hub with the square ends up against the hub faces. Keeping the wheel still, scribe round the two pieces on to the hub faces.

The keyway is now marked on both sides of the hub and the lines at the edges of the hole on both sides may be joined by a square or straight edge.

If a taper key has to be fitted, the two marking-off pieces will be of different heights and this difference will have to be calculated.

The two prepared templates need not be very long, in fact it is preferable sometimes to prepare two pieces of the correct key section from 16 s.w.g. mild steel.

When the keyway in the shaft is shorter than the hub, a modification of the above method may be used.

First fix the two prepared key pieces into position in the

shaft keyway. Place a straight edge against the pieces on one side and scribe a line along the shaft. Do the same on the other side.

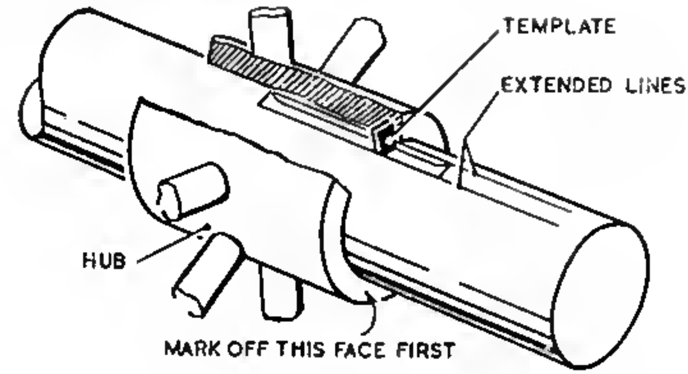
The positions of the sides of the shaft keyway have now been extended. Slide the wheel hub over the keyway, insert one prepared piece on that side of the hub near to the scribed lines and mark round it. Now remove the prepared piece, slide the wheel along until the unmarked side of the hub is over the keyway. Insert the template again, and carefully positioning the side lines of the marked hub keyway so that they coincide with the lines on the shaft, mark round it on the second side of the hub.

The artisan may find himself a little bewildered by the above description. In Fig. 86 the two steps are clearly shown, and, if the text is read carefully in conjunction with the diagram, the idea will be clear and plain in a few minutes.

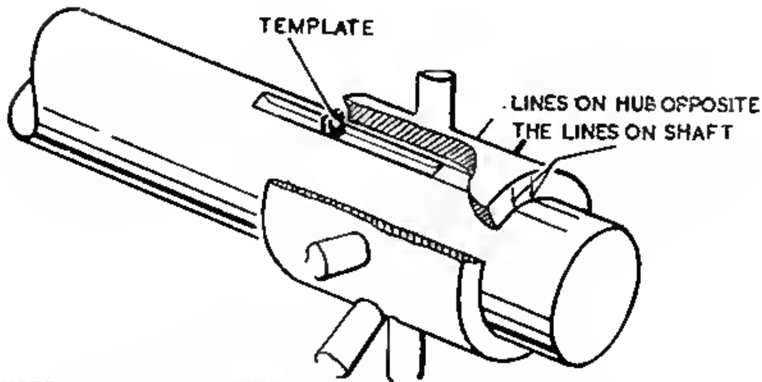
Supposing it is not convenient to use either of the methods so far mentioned, and the keyway has to he marked when the wheel is off the shaft, or without reference to a keyway, as, for example, when a saddle or simple flat key is to be used, a skilled man would lay one rule or straight edge across the hole and measure with another rule from the edge of the hole, setting the first rule central. He would then scribe a centre line each side of the hole, that is above and below, and mark out the keyway width from this, afterwards transfering the lines through the hub to the other side with a square. If this is done carefully, a good approximation of the keyway position will be obtained, but it is recommended that the keyway is left .010 in. short of the lines for final fitting.

The lines should be checked by marking out the keyway width on a shaft, sliding the pulley on the shaft over the lines, and seeing if lines on hub and shaft coincide at both sides of the hub. This check should always be made when the hub is marked without the aid of a finished keyway.

Whichever method is used, if the cutting is to be done by hand, the keyway sidelines must be marked along the inside of the hole, and the keyway must be marked on both sides of the hub.



FIRST POSITION



SECOND POSITION

Fig. 86

Cutting the Keyway in the Hub

First of all centre-punch small witness marks on the lines.

Use the diamond and flat chisels first, cutting grooves right through with the diamond chisel and following with the flat chisel, then completing the sequence by filing up approximately true each time, until the keyway approaches full size. Make the keyway flat at the first sequence of operations.

Test the bottom of the keyway with a straight edge, and use some form of gauge to test for correct depth relative to the hole face throughout its length. A special gauge may be made for this purpose. See Fig. 87 (a).

Unless the hub is exceptionally big, filing will be much simpler than filing in a shaft keyway, and the fitter will choose an appropriate file at each stage of the operation.

For instance, when the keyway is nearly to size it is risky to use a square file to file side and bottom together. The result will not be square, and a triangular file will be more

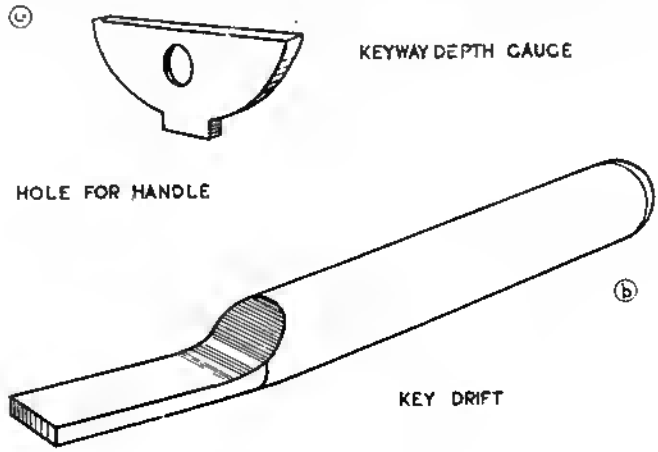


Fig. 87

suitable to file one face at once. It is sometimes advisable to adapt a file to a certain operation by grinding clearances or " blind " sides on it.

Leave the keyway a little small to allow for final fitting in position. The importance of clearly and accurately marking out the keyway before attempting to work on it cannot be too heavily stressed.

Use copper sulphate on a steel or cast-iron machined boss, and scribe the lines deep. Use a good square to transfer lines through the hub, and take care not to bend the blade when scribing. A curved scriber may have to be used. If the wheel has spokes, cut the keyway in line with the centre of a spoke, so lessening the risk of weakening the hub.

Fitting the Key

Flat sunk key. The key is first fixed tight in the shaft keyway, then moistened with oil on sides and top. File a small chamfer on the keyway edges at the hub face and slide the wheel up until the key is opposite the hub keyway. Draw it up tight by hand until it sticks, and drive the hub on to the key using a wooden mallet.

The blows should be strong and firm but not vicious, and when it becomes apparent that the key is too tight in the hub for the latter to move any more, drive the hub off the key, take it off the shaft and carefully file off the marks left by the key. Don't file too much off. The key must be tight all along at the final fitting.

When it is found that the keyway is not quite central between the lines, instead of filing *both* sides of the hub keyway, file only that side which is farthest from the line.

Continue the operation until the key is sunk far enough through the pulley (usually right through).

Before the hub is driven on for the last time, wipe the key and pulley keyway free from oil and assemble dry.

Taper and Taper Gib Keys

The flat at the bottom of the shaft keyway will be longer than the key, and the key may be first fitted into the shaft in such a position that it may be driven forward or backward if necessary.

Continue as before, oiling the key after assembly in the shaft. The purpose of this oiling is to help the hub to come off the key easily, and to prevent scoring. The oil is removed on final assembly.

When fitting a taper key, the top as well as the sides has to be a tight and true fit all along.

The usual practice is to file the key on top, and file the hub on the sides. If a good job is made of the hub keyway, very little filing will be necessary on top of the key.

Final tightening is carried out by striking the key, driving it up tight. A drift will be used on an ordinary taper key, but a gib key, of course, will be struck on the jib.

If the key is seating properly it will feel, and sound, solid.

Saddle Key

First fit the key into the hub keyway before assembly on the shaft. Take great care that the marking off is correct on the hub and work strictly to the lines.

Keep on tapping the key in, then taking it out and filing off the surplus metal inside the hub keyway, until the key is sunk right down to the bottom. The fit at the sides need not be so tight as the fit required for a flat sunk key, nevertheless the key must not be slack and should tap in.

If key and keyway have been made to correct size, there will be only a small amount, say .010 in., to be removed fom the top of the key.

The pulley is put on the shaft and the pulley keyway edges on the hub face, chamfered slightly. The pulley is fixed or held firmly by an assistant, and the saddle key driven forward into the hub, using a soft mallet, and driven out again with a drift.

The key should mark on top only and may be put in the vice between soft jaws and the marks carefully filed off.

The process is continued until the key is right home in the pulley. Oil will be used which must be removed before filing. Wooden mallets are not suitable for driving keys : a hammer and a piece of copper or brass is much better. A saddle key must be a good tight fit between the shaft and the bottom of the pulley keyway.

If it is found that a key goes a little more easily into one end of a keyway than the other, put it in from that end. There are very few fitters who can file a keyway so perfectly that there is not the slightest difference between the depth measured at any point throughout, and there is usually a slight taper.

Flat Keys

Like the saddle key, the flat key may be first fitted into the hub keyway and then assembled by filing a small amount off the top of the key.

Feather Keys

The fitting of feather keys should present no difficulty. The pulley keyway is made a little wider than the key to allow a sliding fit.

If the feather key is held by a countersunk screw, drill and countersink the key, fit it in the keyway and mark the position of the tapped hole with the key in place.

Coned and Keyed Shaft Ends

First check the taper of the cones on shaft and pulley, using a little red lead or blue on the shaft and rotating the pulley once or twice in position. If this is correct, assemble the key in the shaft first, and fit the pulley by filing the hub keyway as usual.

The approach of the keyway to the key, instead of being endways, will be from the top to the bottom, and it is recommended that after each marking the whole keyway faces are filed behind and including the marks as far as the bottom of the keyway.

Extraction of Keys

Before attempting to take out the key, thoroughly clean the area in which you have to work, especially the shaft, hub and key. Make sure there are no screws or wedges hidden by dirt, and remove patches of oil which may cause accidents.

In all cases remove the belt from the pulley, and be certain that there is no possibility of the shaft being run under power while work is in progress.

Don't leave tools, nuts, screws, etc. in or on the pulley, and make sure that you can work in safety and comfort.

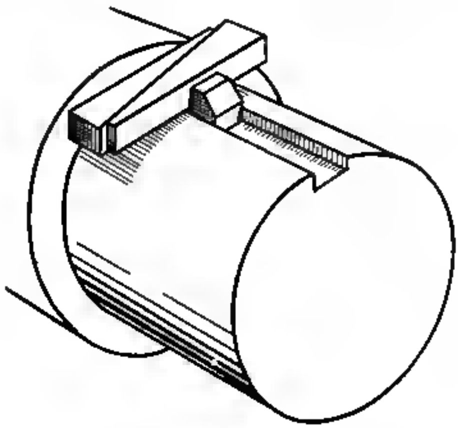
Taper Keys

To extract a plain taper key use the drift shown in Fig. 87(*b*). This can easily be drawn out and bent by the blacksmith and should bear against as great an area at the key end as possible. Strike a number of firm, true blows in preference to one very forceful blow. If this is unsuccessful, clamp two suitably shaped thick pieces of steel round the shaft and introduce two small jacks or two sets of wedges opposite to each other between the steel clamps and the wheel boss. Tighten up hard and try the drift again. The extra power exerted by the jacks or wedges tending to force the boss off the key may make all the difference.

Gib Keys

The gib facilitates the removal of the key and, if the key was properly fitted in the first place, a blow with a hammer against a spanner hooked between the gib and the hub face will " start " the key and it can then be easily drawn out. If the key is obstinate it is not recommended that this method be persevered with.

Another method of extracting gib keys is shown at Fig. 88. Two wedges, tapered as shown, are placed between the gib and the hub and tightened up by striking with a hammer.



KEY EXTRACTION USING WEDGES

Fig. 88

An obstinate key may yield to this treatment, but if it does not, try striking the rim of the pulley directly opposite to the key with a wooden mallet, the wedges being tight. That generally does the trick.

Notice that two wedges are used, therefore the thrust is truly along the centre of the shaft, but if only one wedge is used the force does not act in the right direction, and the gib is liable to be bent or even twisted off.

Never use a chisel as a wedge.

Correct wedges should be of the form of right-angled triangles of about 5°-10° taper.

Oil the sliding faces before use. Sometimes if the key has been fixed for some long period in an exposed position and is consequently rusted up, the three methods given so far may be unavailing.

As a last resource a blowpipe flame may be played evenly round the wheel hub to raise the temperature. The hub will expand and the key may then be driven out. This extreme method is useful for extracting keys other than gib keys also, but the artisan should never adopt it without first obtaining the sanction of a superior.

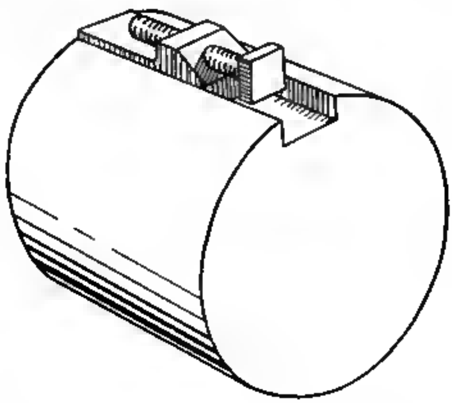


Fig. 89

Another method of extracting a gib key is shown at Fig. 89. In this example the gib head was drilled and tapped before the key was fitted.

Before attempting to remove the key make sure that the end of the keyway in the hub which has to pass over the key is free from burrs. Conversely, if the key extends outside the hub be sure the key is free from burrs. There are so many circumstances that may preclude the use of well tried systems of key extraction that there is often necessity for the fitter to use his own inventiveness to design some special aid to extract the key.

Wheels differ so much in shape that a part of the wheel may make it impracticable to drive wedges between a hub and a gib head for instance, and it may be advisable to make up a special cranked tool or lever to force the key out. When the

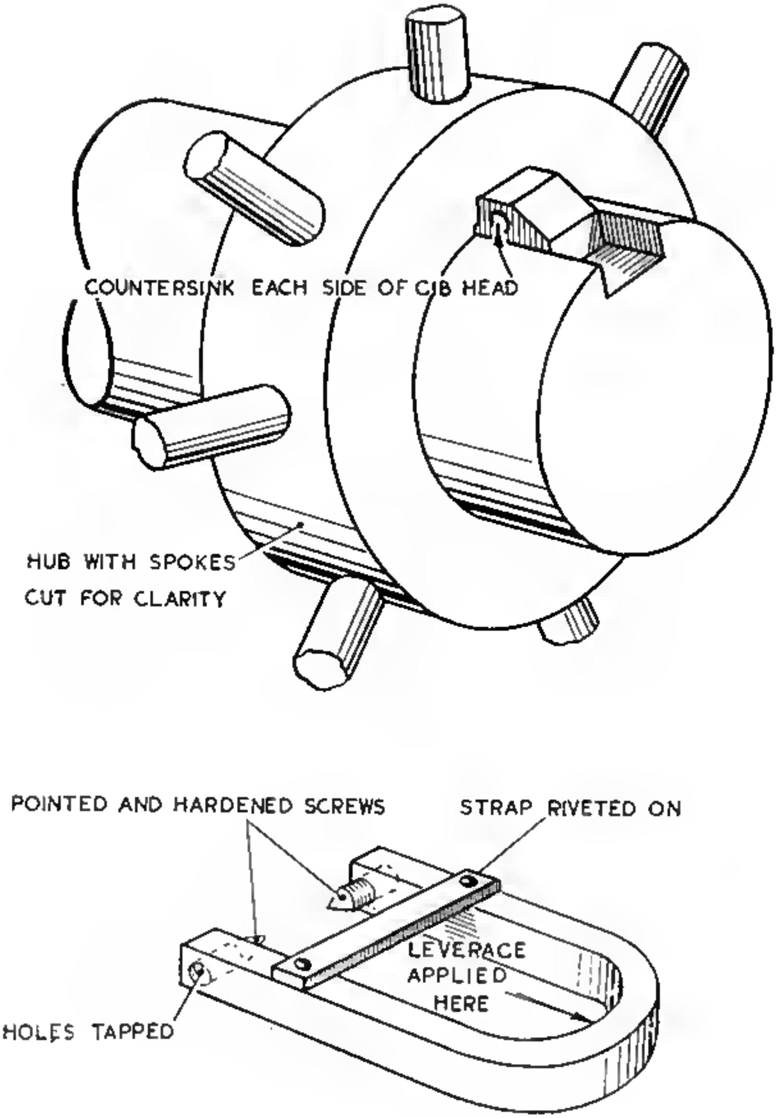

COUNTERSINK EACH SIDE OF GIB HEAD
HUB WITH SPOKES
CUT FOR CLARITY
POINTED AND HARDENED SCREWS
STRAP RIVETED ON
LEVERAGE
APPLIED
HERE
HOLES TAPPED

Fig. 90

wheel is near the end of the shaft the fitter has most scope for inventiveness, and all kinds of arrangements may be successfully employed.

The idea is to design something to grip the key first. It may be possible to drill a hole in the gib head, or, if the gib is a fair distance from the hub, a hole may be filed in a plate and slipped over the key, but if the gib head is right up against the hub the method shown in Fig. 90 may be tried.

Sometimes it is advisable to spot-weld a headless bolt on to the gib.

Having gripped the key a form of leverage must be applied, and here again circumstances and location of the pulley are dominating factors. The fitter has plenty of scope for ingenuity and a little careful thought and attention will nearly always reveal a way.

Flat Sunk Keys

In this case the key is only binding on the sides and, if the keyway is long enough, the key may be driven straight out with a drift. However, some flat sunk keys have radiused ends and are fitted into a slot of the same length as the key. If that is so, the key cannot be " started " and the pulley has to be driven, drawn or pushed off.

If the pulley is near the end of a shaft, an attempt to draw the pulley off in the following way will often prove profitable.

Two or more hook draw bolts grip the pulley, their threaded ends extending further back than the end of the shaft where they pass through a plate butting against the shaft end. Nuts are put on the draw bolts and tightened up evenly.

If the shaft has a centre recess, a screw may be used in the centre of the plate instead of tightening the draw-bolt nuts.

The screw end is turned conical to fit the centre recess in the shaft and hardened.

An obstinate pulley may sometimes be " joggled " off by striking the rim of the pulley at opposite points while some force such as drawing or pushing is applied. As the key was originally driven in from one side, it will obviously come out easiest the same way. So if it does not move after a trial at one end, try the other end.

Saddle keys may be driven straight out with a drift. A little oil on the shaft in the path of the key will help.

Flat Keys

As the flat on the shaft is sometimes only a little longer than the key, the pulley must be moved, but it is a good plan to attempt to " start " the key first using a drift.

Circumstances will decide the best method in any particular case. It is not possible to cover every situation, but enough information has been given to enable any intelligent person to set about key removal in a businesslike and efficient manner. In all cases where some difficulty is experienced, first try soaking the key and keyway with some penetrating oil: several reliable brands are on the market. If oil is not available use paraffin.

Extracting obstinate keys is often a tiring and exasperating job and the artisan is warned that his efforts may not meet with success at once, even if he correctly carries out the instructions given. It is jobs such as these that try the temper of a workman and, whereas one man will quickly lose his temper, strike too heavy a blow or use some unfair leverage resulting in breakage or injury to himself, the true craftsman will persevere unruffled and always succeed.

CHAPTER XIX

RIVETING

No book on fitting would be complete without some mention of riveting. Whereas bolts and nuts can always be undone, riveting is a more permanent form of fastening, and pieces so secured cannot be taken apart unless the rivets holding them are destroyed.

It will not be possible in a chapter to go into full details about every kind of riveting. Such a task could occupy a whole book.

Consider how many different kinds of rivets are seen in everyday life. Rivets on motor cars, on bicycles, on perambulators, on aeroplanes, on bridges, on pots and pans, on spectacles and even on reins to restrain a baby.

The rivets on a bridge may be of mild steel, those on an aeroplane of stainless steel, aluminium or duralumin, and one would be almost sure to find an aluminium or copper rivet in the kitchen.

Whatever kind of rivet is used the principal requirements of its function are these :—it must be tight, it must be perfectly straight after riveting, it must not be beaten so severely that the structure of the material is destroyed.

Both ends of the rivet must be of the correct shape laid down, and the material must be held flat and truly together without any surplus or undesirable matter in between.

We will begin by considering a simple form of riveting, that is a mild-steel, cup-head rivet, holding two plates together, and having a cup head formed on the rivet " tail."

Assuming that the plates are quite flat, the first operation is to mark them off ready for drilling and the drill has to be selected to suit. When the rivet is beaten, it should swell and fill the hole. If the hole is too small, say of the same nominal

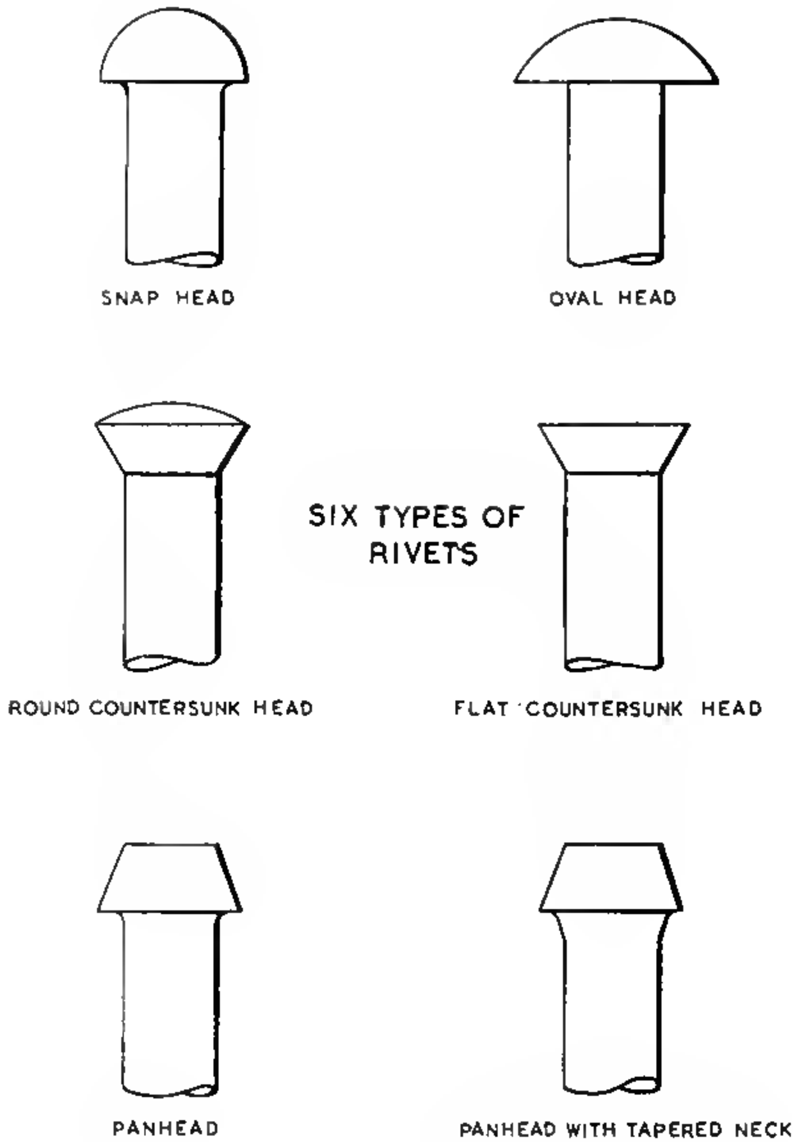

SNAP HEAD
OVAL HEAD
SIX TYPES OF RIVETS
ROUND COUNTERSUNK HEAD
FLAT COUNTERSUNK HEAD
PANHEAD
PANHEAD WITH TAPERED NECK

Fig. 91

size as the rivet, it may be difficult to enter the rivet and if there is a lot of riveting to be done much time will be wasted.

The clearance in the hole depends to some extent on circumstances such as the length of the rivet, and the material from which it is made, but as a guide, and for general engineering work, if the rivet is not more than four times longer than its diameter, 1/64 in. clearance will be satisfactory between and including rivets of ¼ in. diameter up to $\frac{5}{16}$ in. diameter. Larger rivets are usually riveted hot, and more clearance may be allowed, say 1/32 in. *Note.*—The length of a rivet is measured from underneath the rivet head for cup-head and similar rivets, but overall for countersunk rivets with one or two exceptions. For rivets of less than ¼ in. diameter, 1/64 in. is too much to allow. For instance a No. 30 drill is suitable for a ⅛ in. diameter rivet.

After drilling, the holes must be "deburred" on both sides. Small holes can be "deburred" by means of a larger drill secured in a file handle; larger holes under the drilling machine.

The purpose of deburring is to remove the burr left by drilling. On no account must the holes be excessively countersunk. Just remove the burr. That is all.

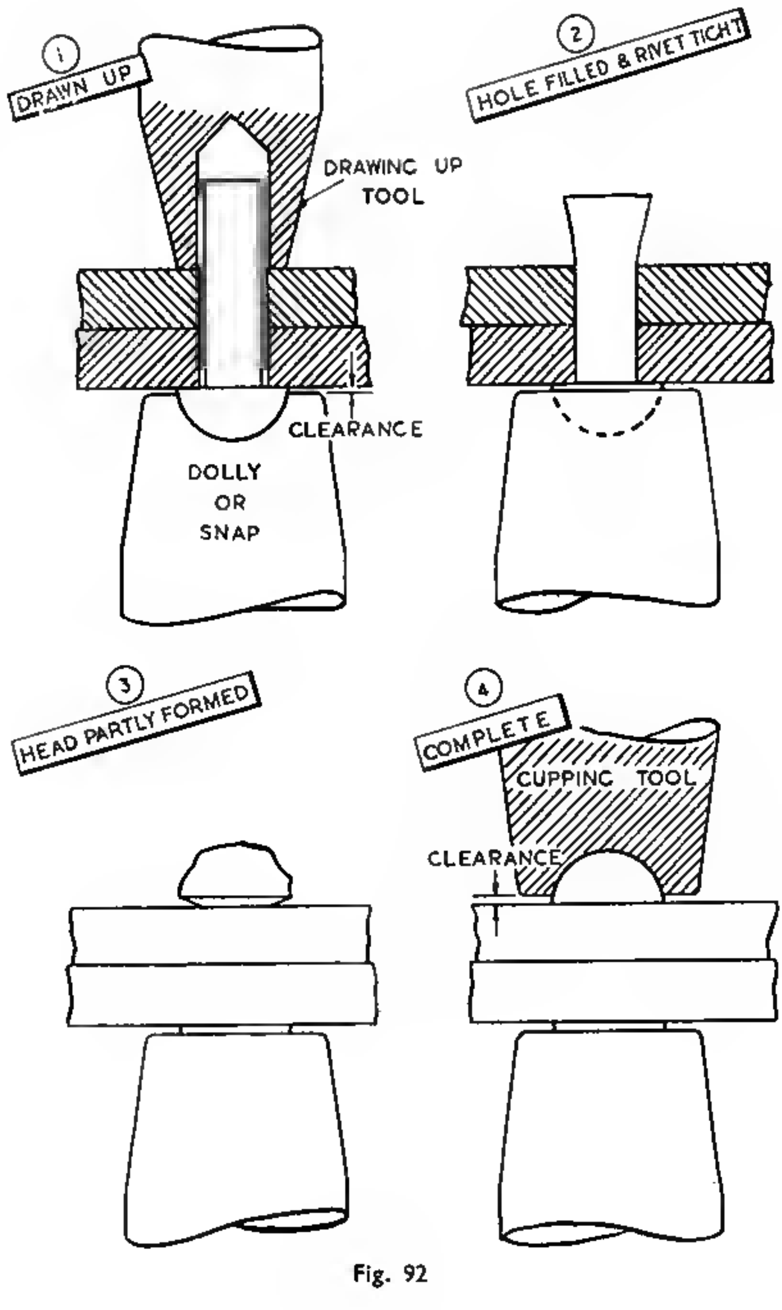
How long must the rivet be so that there is enough metal to form a cup head similar in size and shape to the existing rivet head?

As a general rule, if a length equal to one and a half times the rivet diameter is left proud of the work face, a very satisfactory cup head may be formed, providing the hole is not too large and a cupping tool of correct size is used. Some fitters cut rivets to length on shears, and it does save time although it does not do the shears any good, but a sawn-off rivet flows more evenly and simplifies production of the mushroom shape which must be formed by the ball pane of the hammer.

Of course, if rivets of correct length can be obtained, cutting is eliminated.

The rivet has to be firmly supported.

The usual support for small work is a "dolly" (see Fig. 92) held in the vice, having a piece of steel underneath so that it



1
DRAWN UP
DRAWING UP TOOL
CLEARANCE
DOLLY OR SNAP
2
HOLE FILLED & RIVET TIGHT
3
HEAD PARTLY FORMED
4
COMPLETE
CUPPING TOOL
CLEARANCE

Fig. 92

sits solid against the bottom of the vice. A cast-iron block support is very satisfactory, having a recess if necessary to fit the rivet head. Sometimes a long dolly has to be used, held against the rivet by an assistant. The progressive stages of riveting are shown in Fig. 92.

First the rivet is inserted and drawn up by means of a drawing-up tool. The rivet must now be swelled to fill the hole.

Start this operation using the flat of the hammer until the rivet has filled the hole and tightened up. Then roughly form the cup head using the ball pane. Finish off with the cupping tool. Refer to Fig. 92.

Notice at (1) that the dolly supports the rivet only and is clear of the material being riveted. This is very important because, if the dolly face butts up against the face of the work before the rivet is at the bottom of the recess, there will be clearance between the rivet head and the work, consequently the rivet will dance when struck and will not pull up tight. Furthermore the work will be marked by the dolly face. Incidentally, the dolly must have a countersink or recess of the right shape and depth so as not to mark the rivet head.

Be careful during operation (3). Nothing is to be gained by trying to form a perfect head with the ball pane of the hammer. Form the head roughly and bring it to shape with the cupping tool.

Another warning! Strong young men in their 'teens enjoy, and like to show, their strength, but it should be borne in mind that a $\frac{1}{4}$ in. diameter mild-steel rivet is not proof against a vicious attack by an enthusiastic and powerful youth, and he is quite able to beat a rivet of that size into a state of crystallisation, in which state it is weak and may snap off under very small strain.

At (4), Fig. 92, the cupping tool is shown in section. Notice that the tool is just clear of the work face so as not to leave a mark. If the rivet is too long a skirt of metal will be left round the bottom of the rivet head, and when the rivet is too short the head will be improperly formed and the cupping tool will mark the work. The result in both cases is scrap.

The most serious fault is when the two heads, that is the head supplied on the rivet and the head formed by the fitter,

usually called the " tail," are not in line, proving that the rivet is either bent or partly sheared. Such a rivet is highly unsatisfactory and dangerous and must always be taken out and replaced. The commonest cause of this fault is using a hole too large for the rivet.

So far we have dealt with one kind of rivet only, the cup-head, and we have assumed another cup head has to be formed in the riveting operation, but frequently the tail of a cup-head rivet is beaten into a countersink.

The countersink may be of such depth that the rivet fills up flush when a length of rivet equal to three-quarters of rivet diameter is left proud of the work face.

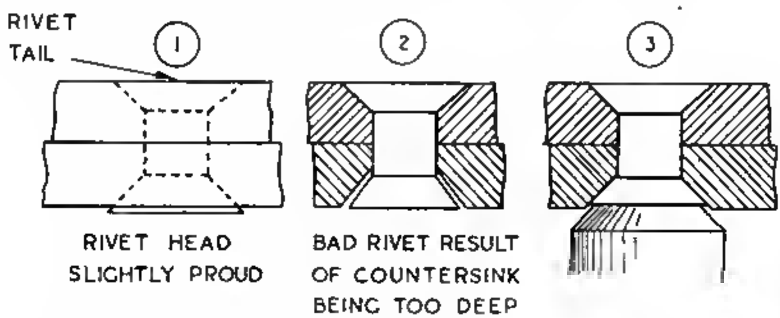


Fig. 93

There is no difficulty in this kind of riveting. The rivet is first drawn up, swelled, using the hammer flat, beaten evenly into the countersink with the ball pane, and finished off with the flat face of the hammer.

The fitter may note that the shape of the rivet head on both sides of the plate is determined by conditions. For instance, the steel rivets holding the plates on a ship's deck are countersunk on the deck side where people walk, but below, on the underside of the plate, the rivets may have cup heads or any shape that is convenient. A countersunk rivet is shown at Fig. 93.

Take care of the rivet head when countersinking, and leave the head a little proud of the work face and not below the surface.

There is a very good reason for this. When riveting, the

rivet and work are supported by a flat block or a flat-faced dolly, but if the head is below the surface of the work the rivet will not be solid and will not draw up properly.

When it is absolutely imperative that the rivet head be below the surface of the work, or if by accident a hole is countersunk too deeply, use a supporting dolly as shown at (3), Fig. 93. Dollies having a recess of the same shape as the rivet head are only necessary to preserve the shape of the head.

Riveting Plates Together

Plates that are first clamped and then drilled together in preparation for riveting must be taken apart and all the holes deburred on both sides.

Punched holes should have the sharp edges taken off and any slight rise on the plate caused by punching filed off flat.

Riveting causes distortion of the plates.

Supposing two rows of rivets are running parallel. If the work was started at one end and one hole after the other in the bottom row was riveted, the plates would " bow " to some extent and it would be found after a time that it was impossible to enter the rivets as the holes would no longer be opposite.

On the other hand, if one top hole then one bottom hole nearest to it below were riveted alternately, the plates would have less tendency to bow sideways, but the plate on the riveted side would creep over the bottom plate and it would be discovered after a time that the holes were no longer in line.

The best way would be to put one rivet in the top end hole, one in the bottom end hole and, say, one top and bottom in the middle. Then fill up the holes in between. When possible, riveting should be balanced in this manner.

Fig. 94 shows twelve rivets entered in a given order to avoid distortion of the plates.

Whenever two plates are being riveted with more than one hole, keep at least one loose rivet through the plates other than the first rivet being formed, so holding the two plates in relationship and holding all the holes in alignment. After two rivets are secured, one each end, there is no longer any need for this precaution. Should the holes move slightly out of line, they can be reamed out, but clamp the plates together

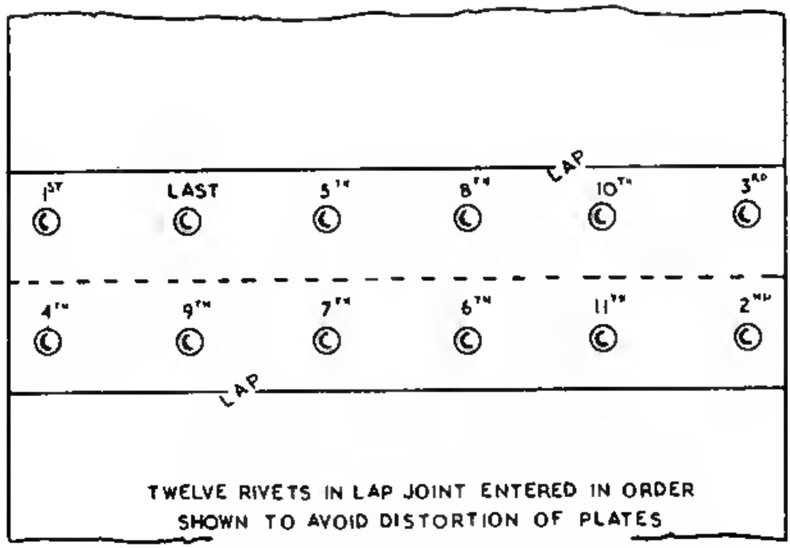


Fig. 94

near to the hole being reamed, otherwise the reamer will force a burr in between them.

General Information

A great deal of hot riveting is done in shipyards by the aid of a pneumatic hammer. The art of this lies in getting the rivet quickly through the hole while it is red hot, and using the hammer lightly at first to swell the rivet and form some of the head before bringing the full power into operation. Rivets burned in the fire, of course, would not be used.

Be careful of the hot shale leaving the rivet, it may cause a painful burn.

Aircraft Riveting

In the inspection of aircraft riveting is very rigorous, and slight faults which would be acceptable in general engineering would cause rejection by aircraft inspectors. Furthermore, the rivets used are made from various metals and alloys, some requiring special heat treatment, and some are given a corrosion-resisting coating before riveting.

Mild-steel rivets in aircraft are sometimes used without any

treatment, but more often they are cadmium-coated before assembly.

Stainless-steel rivets. The fitter will find a toughness and resistance about stainless steel and he is advised to use the hammer to form the rivet head nearer to shape than is necessary with softer materials.

A mild-steel rivet can actually be beaten down with the hammer flat face only, and the cupping tool will do the rest, but this is not so with a stainless rivet, which resists the cupping tool and seems to harden the more the tool is applied, hence the advisability of forming as much of the shape as possible with the hammer, coaxing the material to flow, taking more time over the job and being very careful not to mark the work.

Aluminium rivets are very soft and require a light hammer used with a light touch. They are easily knocked out of line if beaten too hard at the beginning. The rivets are anodised before use.

Duralumin rivets are also given anodic treatment and in addition are " normalised " in a salt bath. The normalisation lasts only two hours, unless the rivets are kept in a refrigerator after normalisation, when the normalisation is prolonged.

The rule in aircraft factories is to use the rivets not longer than two hours after salt-bath treatment. After this period they must be re-normalised, unless a refrigerator is employed.

Duralumin is much tougher than aluminium but is easy to work. It is softer than mild steel.

Aluminium and duralumin rivets appear so very much alike that the manufacturers have given each a distinctive marking. Aluminium rivets have a small dimple like a centre-punch mark in the centre of the head. Duralumin rivets have a letter " D " raised on the head.

Special care must be taken when riveting aluminium plates with duralumin rivets. The rivets are much harder than the plates, and, unless the rivet is firmly supported and skilfully beaten, the holes in the plates will be elongated and the plates themselves buckled.

There are several unconventional forms of riveting in use on aircraft assembly using special tools, but it is felt little

could be gained by explaining at length to the artisan. In passing, however, it may be noted that all rivets are not beaten up. Some are squeezed, and with tubular rivets the ends may be formed by rolling. Aircraft inspection demands that some liquid such as boiled linseed oil be painted between the plates before riveting to prevent corrosion taking place where it could not be detected.

Extracting Rivets

A rivet that is out of line or badly formed must always be removed and replaced.

Chipping the rivet head off with a chisel is *not* the best way. File a small flat on top of the rivet, put a punch mark in the centre and drill down, using a drill a little smaller than rivet diameter, to a depth a little less than the rivet head thickness.

The head may then be carefully chipped off with a blunt chisel, and the rivet driven neatly out with a pin-punch.

How to Make Cupping Tools, Dollies or Snaps

Take a piece of round or hexagonal cast-steel bar and face off both ends square. Put a small chamfer on the end to be driven by the hammer, and a long chamfer on the end to be recessed. Find the centre of this end, put a punch mark and drill down a little deeper than the thickness of the rivet head with a small drill.

Now, if the fitter is clever at drill grinding, he can get a drill of the nearest size applicable and grind it to a rounded shape at the cutting edges. Drill down to the bottom of the small hole with this.

Next find a ball-bearing of approximately the same radius as the rivet head, sit the ball in a recess drilled in a block or strong plate, heat the snap to a bright red locally at the drilled end and, holding it on top of the ball, strike with a hammer until the ball has completely formed a spherical impression.

It may be necessary to heat the punch more than once.

Finally grind or file off the surplus metal until it is just the right depth and harden.

The right depth may be found by trial and error, not on the actual job, of course, but in scrap material. If the snap is for

stainless-steel rivets it must be hardened before being tried and ground off to depth. Mild-steel snaps are suitable for aluminium riveting.

A piece of an old round file will make an excellent snap, but be sure it is properly heat-treated so that the end you strike is soft and the business end only is hard.

CHAPTER XX

TUBE BENDING

LET us first consider what happens when a tube is bent.

The metal inside the bend has to be crushed and the metal on the outside stretched. Take an ordinary eraser in your hand and bend it. Innumerable small wrinkles pucker up inside the bend where the rubber is crushed and outside it is obviously stretched. Exactly the same thing happens when a tube or solid piece of steel is bent, but, whereas the piece of steel has power in itself to resist deformation at the bend, a tube, being hollow, is quite liable to collapse unless it is given strength by being filled with some substance, or unless the bend radius is large enough to distribute the crushing and stretching over such a wide area that the strain at any one place is not great enough to cause failure. An example of the latter case is the steel conduit pipe used to carry wires.

The electrician has a length of wood in which is a slot near the top. The tube is passed through the slot and bent by pressing it downwards. All kinds of complicated shapes are required, but in no case has the electrician to bend a sharp bend, and so the crushing and stretching is never great enough to cause collapse

The smallest radius at 90 deg. an unfilled steel conduit pipe of $\frac{3}{4}$ in. diameter $\times$ 18 s.w.g. thickness will take is about 5 in.

Should the electrician require a sharp bend he uses a special elbow piece supplied to him, threaded at each end into which he screws two straight pieces of tube

Fillings for Tubes

Mention has already been made that strength may be given to a tube by filling it with some substance and making it to all intent and purpose a solid piece The substance must be

easy to put in and easy to take out. In this category we have dry sand, lead, resin, and pitch.

Sand. A suitable plug of wood, lead, or steel is driven tight in one end of the tube and the sand poured in, the outside of the tube being tapped with a piece of wood or a mallet to shake the sand well down. This rapping on the side of the tube must be continued until the sand refuses to sink any more: The second plug is now driven home tight and the tube is ready for bending.

Fine sand gives a much better filling than coarse, even as flour will fill a bag more tightly than peas will.

Lead is heated until it becomes fluid and then poured into the tube which is stopped with a wooden plug, or the tube may be held vertical in a pair of tongs on a piece of asbestos, the lead poured in and allowed to cool. After a few seconds the lead will set sufficiently to be moved.

Warm the tube before pouring in the lead and clean the inside, if necessary. The tube is warmed and thus dried inside to assure that condensation does not take place, causing spluttering when the lead is poured.

It is an advantage to oil, or paint with whiting, the inside of the lead-filled tubes before filling. This treatment assists the tube to empty clean.

Resin and pitch are mixed together for the sake of economy. A common proportion is two parts pitch to one part resin, but this varies according to the weather. In hot weather, add more resin.

Lead plugs are generally used. The plugs may be prepared from small pieces of the tube to be bent, the true end of the piece resting on a flat plate. Oil inside first, fill with lead to the required height, and allow to cool.

Resin and pitch needs " topping up." When the lead plug has been inserted and the tube filled, the mixture will sink down some distance as it cools and a little extra must be poured in to fill up while it is still fluid.

In cold weather all tubes to take a hot filling should be warmed first.

When the tube is bent, the filling must be extracted.

Sand comes out easily when the plugs are removed, but heat

has to be applied to bring out lead or resin and pitch.

Suppose a steel tube was filled with lead and bent. We could extract the lead by applying a blowpipe-flame at the bottom of the tube and moving it up as the lead flows out, but if the tube was of copper, brass or tungam, the heat required to melt the lead may have some injurious effect on the metal, and that is one reason why a resin and pitch mixture is used more often than lead to fill copper and the alloys mentioned, as it has a much lower melting point than lead. However, lead can be used as a filling for copper, brass and tungam, providing sufficient care is taken, but it is never used to fill aluminium tubes.

Tubes filled with resin and pitch are put inside an oven and kept at a temperature of about 250° F. until the mixture runs out into a suitable trough. In modern factories the residue remaining in the tubes is removed by a degreasing plant, but, if this is not available, it can be burnt out with a blowpipe. This last practice although common is rather dangerous in two ways. Firstly, there is some danger of the workman either burning himself or starting a small fire, and secondly there is the danger of the material being damaged or distorted by too much heat. If this method must be used, additional care must be exercised.

Final cleaning is carried out by wire brushes first and then washing in hot water.

Bending the Tube

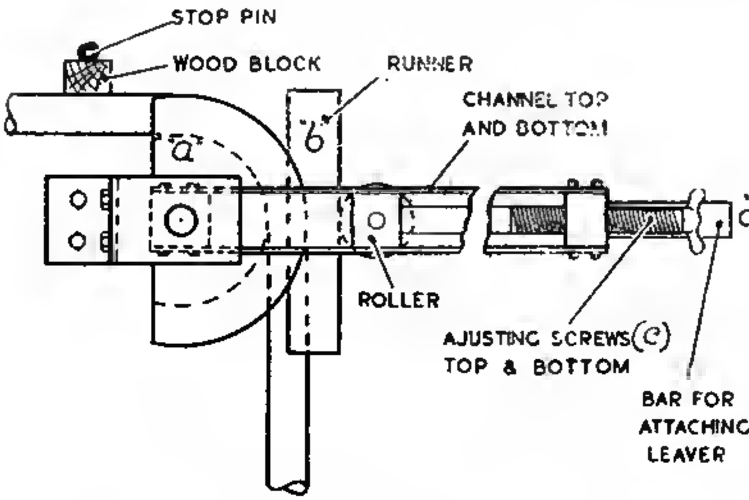
Before bending the tube the fitter makes a wire template of the correct shape. Ordinary mild-steel wire of about 14 s.w.g. is suitable. He constantly applies this template to the work as he progresses.

Fig. 95 shows a plan view of the Hillmoore-type bending machine.

The centre block (*a*) is detachable so that blocks of different radii may be used. Each block has a corresponding runner (*b*) that follows the tube round on the outside as it is bent. The roller butting against the runner is brought up and maintained at the correct tension by the screws (*c*). A lever is attached at (*d*) to pull the tube round.

Some degree of knack and practice is required when adjusting the runner to the correct tension. The operator makes a reference mark in some suitable position so that after the first bend he can give a little more or a little less tension as required. Should the runner be too tight the tube may be broken, and if too slack there is danger of the tube moving during bending, causing several pronounced puckers inside the bend.

The radius referred to on the bend-block is the radius inside



PRINCIPLE OF HILLMOORE TYPE BENDING M/C

Fig. 95

the throat of the bend, but the block and runner are radiused to fit the tube as is obvious from the illustration.

Tubes are also bent by hydraulic power, sometimes in a vertical press, and sometimes horizontally. In the latter case the ram gradually pushes at the centre of the bend against a suitably shaped pad between two pins which supply the staying forces.

It is unlikely that the fitter will have a Hillmoore machine or a suitable hydraulic accessory to bend the odd tube that comes his way, so an arrangement will now be described that is easy to make up, and is very successful. It is known as the

"rod and ring" method. The rod is a round steel bar of suitable strength, and the ring a piece of strong steel tube flattened into an egg shape and bound with a thick string to prevent marking and slipping. (See Fig. 96.)

The tube is secured in the vice between two radiused wood blocks and the ring slipped on. A suitable purchase is taken and the tube levered over, the ring and wooden block being moved along as the bend is formed. If the operation is done skilfully the result will be an almost perfect bend. It should

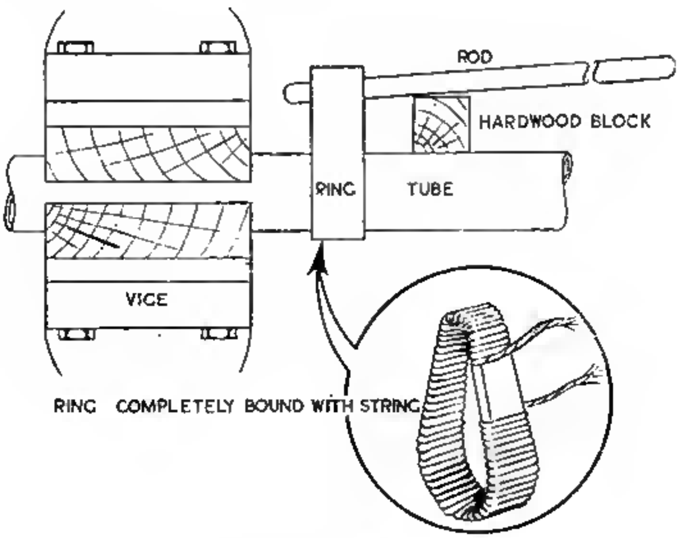


Fig. 96

be noted, however, that difficulty may be experienced if the bend radius is less than six times the tube diameter unless the tube itself is, say $1\frac{1}{2}$ in. in diameter or less.

The rod and ring, of course, have to be proportional in size to the work. It is an advantage if they are welded together, as it is easier to manipulate two articles than three. When a steel tube has to be bent, and it is too strong to yield to the rod and ring method, it may be necessary to heat it.

The tube is filled with dry sand and heated locally in a small forge or by a blowpipe. It may then be held in the vice using wooden blocks and pulled round. Several heatings may be

necessary so nothing is gained by overheating at first, but it is essential that the heat goes right through tube and sand. The heat may be localised by the use of water so that only the part which has to bend is hot. When heat is applied to a sand-filled tube, the sand must be perfectly dry, otherwise steam inside the tube may cause an explosion.

Very ingenious machines have been devised for tube bending, and while some of these bend tubes with remarkable accuracy and perfection, very many of the tubes bent by other methods have to be corrected after bending. In particular, copper and alloy tubes, excepting those of small diameter, pucker or crinkle at the throat of the bend in spite of the filling. These puckers have to be removed.

On the Hillmore machine, where a runner is used, the runner leaves a mark like a seam all round the bend. This has to be smoothed out on important work. Coppersmiths call the operation "codding." The pucker is supported on the inside by a "cod" which is simply a piece of mild-steel rod bent to a suitable shape and having a polished ball of steel welded to one end. The rod is held in the vice and the ball passed inside the tube until it reaches the point where support is required, that is underneath the pucker, and the craftsman using a light hammer with a polished face, begins to beat the pucker, gradually persuading the metal to "flow" into the throat of the bend.

Back and throat swages are also used by coppersmiths to smooth out crinkles and deformations, the tube being supported by a soft pad.

Considerable skill is required on both "codding" and "swaging" and success comes from a combination of experience and "feel."

General

The choice of which filling to use is a matter of common sense. A steel tube having a large inside area may be so heavy as to be unmanageable if filled with lead. Sand would be the obvious choice. If the tube wall should be of a good thickness, heat may have to be applied to bend it. In that case lead could obviously not be used as a filling.

Tubes of small diameter, say up to $\frac{3}{8}$ in., are usually bent without filling unless the wall is very thin. Between $\frac{3}{8}$ in. and $\frac{3}{4}$ in. diameter, sand is suitable for tubes of almost any material.

Aluminium tubes of small diameter are frequently pinched shut at one end in the vice, the sand poured in and settled properly, and the other end closed by a tight wad of paper.

The malleability of some materials may be increased by annealing.

Aluminium. The tube is warmed until resin melts when brought in contact. A line of resin is applied along the tube which may then be placed on an asbestos sheet and heated until the resin browns and burns off revealing a clean surface underneath. The tube may then be bent.

Brass is not usually annealed before bending ; it is, however, sometimes wise to anneal after bending, especially if the bends are numerous or acute. It should be placed on an asbestos sheet, brought carefully and uniformly to red heat and allowed to cool slowly.

Tungam, a special tube alloy, may be annealed before and after bending. It is brought to a blood-red heat and allowed to cool, then filled, bent, emptied, brought to blood-red heat again, and finally allowed to cool off.

Duralumin. Similar treatment to aluminium.

Copper is not heat treated.

CHAPTER XXI

SLIP GAUGES, OR GAUGE BLOCKS

SLIP gauges are square or rectangular blocks of steel, hardened and lapped to a remarkable degree of accuracy.

The surfaces are parallel and perfectly flat so that they may be wrung together and a number of them so secured will be self-supporing. Their use nowadays is universal, and the fitter aspiring to a good class of work must have some knowledge of their use and applicability.

The slips are supplied in three grades: Reference, Inspection and Workshop.

The Reference gauges are the most accurate and are used only for comparison with Inspection and Workshop gauges.

Inspection gauges are used by the Factory Inspection Department.

Workshop gauges are those actually in use by the fitter or machinist.

All three grades are supplied in sets of eighty-one pieces in the following sizes :—

Nine pieces : .1001 up to .1009 inclusive.

Forty-nine pieces : .101 up to .149 inclusive.

Twenty pieces : from .050 rising in increments of .050 up to 1 in. inclusive.

One block 2 in., one 3 in., and one 4 in.

Sometimes there are two additional "protector" slips of .1 in. thickness intended to be used at each end of a combination to confine wear to two blocks only. They should be used whenever possible.

When the slips are clean and free from grease they may be wrung together by pressing one on to the other at the corners first, then sliding them firmly across each other. They will always wring if they are clean and providing, of course, that there is no grit or burrs between them.

When taking the slips apart, it is better to slide them off each other than to attempt to forcibly pull them off.

Selecting the Slips for Use

Suppose it is required to make up a measurement of 3.2497. A person accustomed to using slip gauges would make the necessary calculation mentally, but a surer method for the beginner is to write the problem down as follows :—

Size required	= 3.2497
Removing last figure	.1007*
	3.1490
Next step	.149*
	3.000*

Notice that an asterisk is placed against the selected slip. This prevents confusion and enables slip sizes to be seen and checked at a glance.

The above example is comparatively simple.

Suppose the size required was 1.2894.

Size required	= 1.2894
Removing last figure	.1004*
	1.1890 . . . . . A
	.050*
	1.139 . . . . . B
	.139*
	1.000*

In this case the use of the .050 slip is demonstrated, showing how it it may be utilised to bring a decimal three figure dimension into the range of the forty-nine slips in the set. There is no slip .189 (see A), but when .050 is subtracted .139 is left, which size is obtainable (B).

When the figures behind the decimal point are between .150 and .2, the .050 slip can conveniently be used, but had

the figure at " A " been say 1.789, a better slip to use would have been .650, leaving .139, and effecting a saving in the number of slips used.

Very often the fitter has to make up two slip combinations of the same size.

Suppose it is required to make up two slip combinations of 4.1783 from the same box of slips.

Size required	= 4.1783
Removing last figure	.1003*
	4.0780
First Combination	.128*
	3.950 = 3 in. and .950.
	4.1783
	.1001
	4.0782
Second Combination	.1002
	3.9780
	.138*
	3.840
	.140*
	3.700 = 2 in., 1 in. and .7 in.

The slips selected in the two examples are not the only combination which could be made, of course, but they serve the purpose of showing the flexibility of the set. In the two examples no slip could obviously appear in both combinations from one set. Always use the minimum number of slips in any combination.

When the two .100-in. protector pieces are supplied and the combination is large enough for their inclusion, first subtract .2 in. from the size required and proceed in the normal way.

So far, the use of slip gauges has been represented simply in

the form of a number of slips wrung together which may be used for measuring gaps or distances between faces or pins, etc., but by means of special attachments the scope of slips may be considerably extended.

A set of Johansson attachments consists of four special clamps like the one at (*a*) in Fig. 97.

The two longer clamps have spring-loaded split nuts to facilitate quick screw adjustment, and a tapped hole at one end enabling them to be secured to a special base.

Slip gauges and a " bit " are inserted and the whole assembly constitutes a height gauge.

Other attachments in the same set are: three sets of jaws for use when measuring inside holes, a " bit " or scriber, and a piece having a conical point for use when describing circles.

With reference to the jaws; two sets have semicircles of .1 in. radius and one set of .25 in. radius. The first two sets may be used as .2-in. plugs, one set being slightly longer than the other, enables the first plug to sink into the hole a sufficient distance for location before the second plug begins to enter. A clamp of suitable length is selected for the particular job in hand.

Measuring Hole Diameters

The approximate diameter of the hole is first ascertained. The slips are held in the special clamp and the jaws inserted one at each end as shown at (*a*) Fig. 97.

The diameter of the hole will be the same as the slip combination plus the thickness of the two jaws.

Measuring Outside Dimensions

The same arrangement is useful for measuring outside dimensions, the assembly being used in exactly the same way as a vernier calliper. The gap is extended or reduced by substituting slips of the appropriate denomination required, i.e. to .001 or .0001 in. until exact size is obtained.

Scribing Radii

At (*b*), Fig. 97, the attachment is shown for striking radii either from a centre-punch mark or from a hole.

When striking from a hole, enter the conical point in the hole first, then holding the clamp horizontal and having the slips and " bit " half-tight, press the bit down until it touches the surface of the work.

Fasten up tight and describe the circle.

The slip combination will be the same size as the radius required.

Care of Gauges

Slip gauges are expensive and, if their life and accuracy are not to be impaired, they must be treated with care.

Although the faces are hard, they are not indestructible, and can be scratched and scored by grit or hard substances. They can also be damaged if subjected to a heavy blow.

Only take from the box the slips actually in use.

Keep the lid of the box closed.

Wipe clean before and after use with a chamois leather, and moisten the faces with a good quality vaseline.

Avoid forcing slips between hard faces, or dropping them on concrete floors.

Keep them away from heat, copper sulphate, shale, grinding dust, filings and other injurious matter.

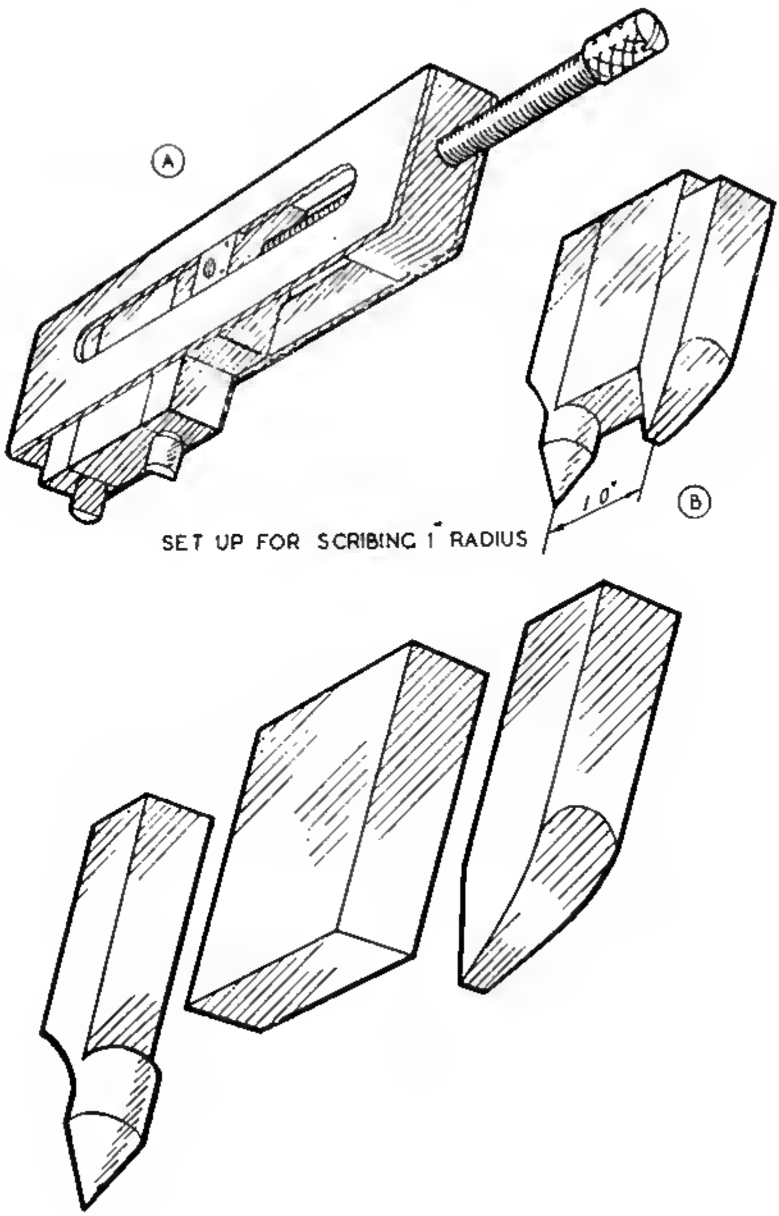


Fig. 97 .

CHAPTER XXII

"DRAWING OVER" A HOLE

ALTHOUGH boxed holes can be drilled fairly accurately in position, greater accuracy results when the holes are gradually brought to full size by a series of drills, a check being taken after every drilling and inaccuracies corrected by drawing over the hole with a round file.

Suppose it is required to drill two $\frac{1}{4}$ in. diameter holes 3.000 in. apart. The holes are first positioned and boxed in the usual way. A drill somewhat smaller than $\frac{1}{4}$ in. is selected for a start, say 15/64 in. The first drill is merely used as a guide, the operation consisting of countersinking, checking with a magnifying glass and drawing over with a centre punch in the required direction until the countersink reaches the drill size. Both holes are treated the same, then drilled with a No. 14 drill and reamed $\frac{3}{16}$ in. Pins are inserted and the centres checked with slip gauges.

Suppose on checking it was discovered that the holes were 0.10 short of 3 in. Assuming one hole to be correctly placed, the centre of the other hole would have to be moved .10, but to accomplish this it would be necessary to file the edge of the hole .020. Fig. 98 explains this, but $\frac{1}{4}$ in. diameter is used in the illustration for simplicity of calculation.

Filing is done as carefully as possible, removing the full .020 from the bottom of the hole and blending in the sides as indicated by the two circles in Fig. 98.

The hole may now be opened out again with a suitable drill and reamed 7/32 in. diameter.

Pins are again inserted and a check made as before with slip gauges. When the holes are correctly positioned to required limits, they may be opened out and reamed full size. It is not always necessary to make up special pins. The

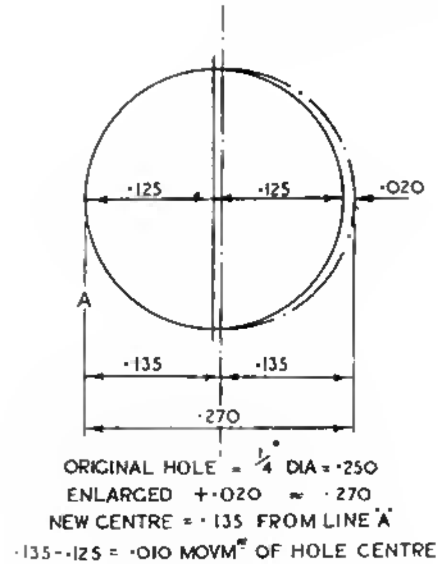


Fig. 98

straight shanks of drills will do, provided they are not scored or burred.

Every drill used for opening out must be properly ground, because if the drill lips are of different lengths, the hole will not be cut away evenly each side when opening out commences.

Use a good drilling machine on which the chuck and spindle run true and allow the opening out drill to "feel" its way.

A stop is preferable to a clamp for preventing the work spinning round unless the hole is bigger than ⅜ in. diameter, when it is advisable, after first correcting the hole positions, using small drills and reamers, to secure a pin in the drill chuck of the same size as the hole.

Bring the drill spindle down and enter the pin in the hole, then clamp the work carefully and open out to the size required.